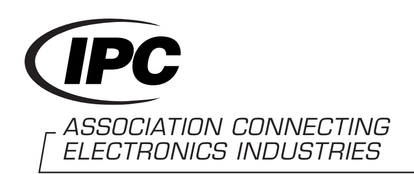


IPC-2581
with Amendment 1

Generic Requirements for Printed Board Assembly Products Manufacturing Description Data and Transfer Methodology



Endorsed by the International Electronics Manuafacturing Initiative (iNEMI)

IPC-2581
with Amendment 1

May 2007

A standard developed by IPC

Supersedes IPC-2581
March 2004

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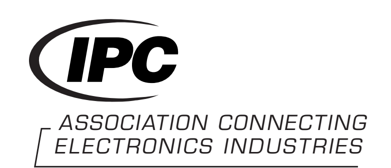
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Developed by the CAD/CAM Convergence Subcommittee (2-17) of the Data Generation and Transfer Committee (2-10) of IPC

Supersedes:
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Users of this publication are encouraged to participate in the development of future revisions.

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Acknowledgment

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1 SCOPE

This standard specifies the XML schema that represents the intelligent data file format used to describe printed board and printed board assembly products with details sufficient for tooling, manufacturing, assembly, and inspection requirements. This format may be used for transmitting information between a printed board designer and a manufacturing or assembly facility. The data is most useful when the manufacturing cycle includes computer-aided processes and numerical control machines.

The data can be defined in either English or International System of Units (SI) units. The format is a convergence of the IPC-2511 “GenCAM” and the Valor Computerized Systems “ODB-X” format structure.

1.1 Focus and intent

The generic format requirements are provided in a series of standards focused on printed board manufacturing, assembly, and inspection testing. This standard series consists of a generic standard (IPC-2581) that contains all the general requirements. There are seven sectional standards that are focused on the XML details necessary to accumulate information in the single file, that addresses the needs of the manufacturing disciplines producing a particular product.

The sectional standards (IPC-2582 through 2588) paraphrase the important requirements and provide suggested usage and examples for the topic covered by the sectional standard.

1.2 Notation

Although the data would be contained in a single file, the file can have different purposes as described in Section 4. The XML schema used for this standard follows the notations set forth by the W3C and is as follows:

element – Element appears exactly one time

element? – Element may appear 0 or 1 times

element* – Element may appear 0 or more times

element+ – Element may appear 1 or more times

Any IPC-258X file is composed of a high level element (IPC-2581) that contains up to six sub-elements:

Content – information about the contents of the 258X file

LogisticHeader – information pertaining to the order and supply data

HistoryRec – change information of the file

Bom – Bill of Materials (Material List) information

Ecad – Computer Aided Design (engineering) information

Avl – Approved Vendors List information

2 APPLICABLE DOCUMENTS

The following documents contain requirements which, when referenced, constitutes provisions of IPC-2581. At the time of publication, the editions indicated were valid. All documents are subject to revision and parties entering into agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below.

The revision of the document in effect at the time of solicitation **shall** take precedence.

IPC-T-50 *Terms and Definitions for Interconnecting and Packaging Electronic Circuits*

IPC-2501 *Definition for Web-Based Exchange of XML Data*

IPC-2524 *PWB Fabrication Data Quality Rating System*

IPC-2511 *Generic Requirements for Implementation of Product Manufacturing Description Data and Transfer XML Schema Methodology*

IPC-2571 *Generic Requirements for Electronics Manufacturing Supply Chain Communication - Product Data eXchange (PDX)*

IPC-2576 *Sectional Requirements for Electronics Manufacturing Supply Chain Communication of As-Built Product Data - Product Data eXchange*

IPC-2577 *Sectional Requirements for Supply Chain Communication of Manufacturing Quality Assessment - Product Data eXchange (PDX)*

IPC-2578 *Sectional Requirements for Supply Chain Communication of Bill of Material and Product Design Configuration Data - Product Data eXchange*

IPC-7351 *Generic Requirements for Surface Mount Design and Land Patterns*

2.1 Documentation conventions

The XML file format standard and the XML Schema definition language standard, as defined the by World Wide Web Consortium (W3C), have been adopted by IPC for use in the IPC-2500 series of standards.

In addition to the text based schema notation this document provides graphical representation of the structure of the file format. The XML diagrams are designed to effectively illustrate the structure and cardinality of elements and attributes that make up any IPC-258X file. The notation in the graphics does not provide a complete visualization of the schema definition for the file format, but it does provide a good top down overview. Should there be any conflict between the graphical notation and the schema notation, the authoritative definition is the schema notation.

Table 1 provides an overview of the graphical notation used in the document.

Table 1 Graphical Notation Overview

<table>
<tr><td>This diagram depicts an element named AnElement that is of type TypeB. There is one attribute, named anAttribute, that is of type double. The attribute is required.</td><td>AnElement
TypeB
anAttribute
double</td></tr>
<tr><td colspan="2">Example:
<AnElement anAttribute="14.44e-3"/>
Note that all attribute values must be enclosed in quotes, regardless of type.</td></tr>
<tr><td>This diagram depicts an element with two attributes. The attribute anAttribute is required. The "?" in the circle indicates that the second attribute, anOptionalAttribute, is optional. Both attributes are of type string.</td><td>AnotherElement
TypeA
anAttribute
string
?
anOptionalAttribute
string</td></tr>
<tr><td colspan="2">Examples:
<AnotherElement anAttribute="red" anOptionalAttribute="a string" />
<AnotherElement anAttribute="blue" /></td></tr>
<tr><td>The element OneToManyOrElements is the parent of an unordered list of one or more instances of the elements AnElement and AnothertElement. The "+" indicates the occurrence is one to many and the angled lines indicate this is a choice relationship ("|") between the children elements.</td><td>OneToManyOrElements
+
AnElement
TypeB
AnotherElement
TypeA</td></tr>
<tr><td colspan="2">< OneToManyOrParentElement>…</td></tr>
<tr><td>The absence of an occurrence bubble declares that one and only one occurrence are allowed. The AnOrParentElement can have one of AnElement or AnotherElement as a child element.</td><td>AnOrParentElement
AnElement
TypeB
AnotherElement
TypeA</td></tr>
<tr><td>The '*' in the occurrence bubble indicates the choice is from 0 to many.</td><td>ZeroToManyOrElements
*
AnElement
TypeB
AnotherElement
TypeA
AThirdElement
TypeB</td></tr>
<tr><td>This diagram depicts an element, From2to3Elements. The element has no type and no attributes. It can have from 2 to 3 sub-elements of either AnElement or AnotherElement.</td><td>From2to3Elements
2
3
AnElement
TypeA
AnotherElement
TypeB</td></tr>
<tr><td>This diagram depicts an element, AParentElement, of type AParentElementType. This element has one attribute, attributeOfParent, which is optional. The lines with square corners indicate that occurrences of AnElement and AnotherElement must appear in the order by the illustration on the right where the top element is addressed first and AnotherElement is addressed secondly.</td><td>?
attributeOfParent
string
AParentElement
AParentElementType
*
AnElement
TypeB
anAttribure
qualifiedName
?
AnotherElement
TypeA
anAttribute
string
?
anOptionalAttribute
string</td></tr>
</table>

This diagram depicts a type, AParentElementType, that contains a sequence starting with one of AThirdElement or AFourth element followed by 0-n AnElement and an optional final AnotherElement.	attributeOfParent string AThirdElement TypeB AFourthElement TypeA AParentElementType AnElement TypeB AnotherElement TypeA

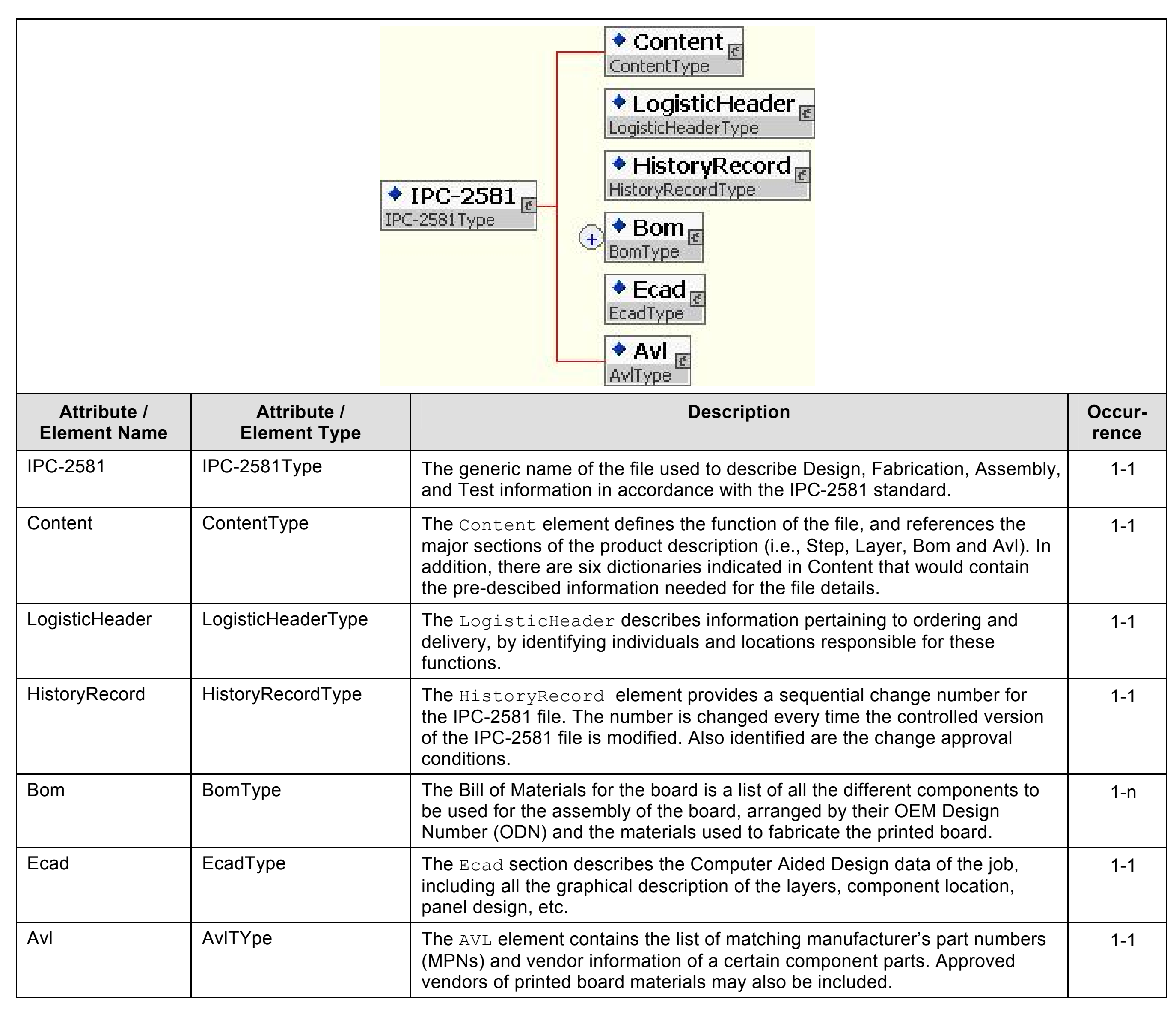
3 REQUIREMENTS

The XML schema contained in this document describes the structure of a generic computer-aided manufacturing 258X exchange format. The document specifies data elements specifically designed to establish the information exchange related to the data needed by printed board manufacturing, and assembly including inspection of those products.

The XML schema defines the configuration of mandatory and optional elements, as well as mandatory and optional attributes. The Top Level (TopElement) of the schema contains six major elements. The schema notation specifies that the 6 top-level elements are required to appear in the order shown in Figure 1. The order of appearance in the file is significant. For instance, the appearance of graphics on a layer is dependent on the order of appearance in the file. The order is also important because elements often reference information that is defined elsewhere in the file in order to eliminate redundancy within the file. The file is structured to allow all references to be resolved in one pass.

An implementation of the XML schema must be able to facilitate the reading and/or writing of all characteristics defined within the requirements stated in the `Mode` function of this standard. Some tools may have only read capability; some may have only write capability. Some tools may have both read/write capability. All schema defined in the standard as mandatory (1-1, 1-n occurrences) **shall** be executed as appropriate. Tool providers **shall** identify their capability by Mode Level (Full, Design 1, 2 or 3, Fabrication 1, 2, or 3 etc.) plus 2581R; 2581W; or 2581RW.

Each element has a specific function or task. Accordingly, the information interchange for a specific purpose is possible only if that element is populated. The ability to select those characteristics that are appropriate for a given task makes the schema a robust methodology for defining only those areas and characteristics that are necessary to produce a given product. Figure 1 shows the children elements of the Top Element (IPC-2581).



Attribute / Element Name	Attribute / Element Type	Description	Occur-rence
IPC-2581	IPC-2581Type	The generic name of the file used to describe Design, Fabrication, Assembly, and Test information in accordance with the IPC-2581 standard.	1-1
Content	ContentType	The `Content` element defines the function of the file, and references the major sections of the product description (i.e., Step, Layer, Bom and Avl). In addition, there are six dictionaries indicated in Content that would contain the pre-descibed information needed for the file details.	1-1
LogisticHeader	LogisticHeaderType	The `LogisticHeader` describes information pertaining to ordering and delivery, by identifying individuals and locations responsible for these functions.	1-1
HistoryRecord	HistoryRecordType	The `HistoryRecord` element provides a sequential change number for the IPC-2581 file. The number is changed every time the controlled version of the IPC-2581 file is modified. Also identified are the change approval conditions.	1-1
Bom	BomType	The Bill of Materials for the board is a list of all the different components to be used for the assembly of the board, arranged by their OEM Design Number (ODN) and the materials used to fabricate the printed board.	1-n
Ecad	EcadType	The `Ecad` section describes the Computer Aided Design data of the job, including all the graphical description of the layers, component location, panel design, etc.	1-1
Avl	AvlTYpe	The `AVL` element contains the list of matching manufacturer's part numbers (MPNs) and vendor information of a certain component parts. Approved vendors of printed board materials may also be included.	1-1

Figure 1 The IPC-258X children element

3.1 Rules concerning the use of XML and XML Schema

The rules required to define syntax and semantics of the 258X file format notation have been simplified by the adoption of the W3C standards for XML Schema and XML file formats. These two standards are well specified by the W3C. The popularity of these standards has lead to the development of many commercial and open source software tools and libraries that conform to the W3C standards.

A 258X file begins with the <258X revision = ”2.0”> tag and end with the </258X> tag. The content between these tags must match the .xsd definition of the 258X element as defined by the IPC-2581 through IPC-2588 XML Schema.

3.1.1 File readability and uniformity

A valid 258X file must conform to the W3C Canonical XML format. The format is defined by the http://www.w3.org/TR/xml-c14n specification. Software tools exist that will take malformed XML and automatically generate Canonical XML.

3.1.2 File markers

An optional checksum can be appended following the </258X> tag. The checksum is an MD5 message digest algorithm (see Internet RFC 1321: http://www.ietf.org/rfc/rfc1321.txt) that is base64 encoded. The checksum starts with the "<" character of the <258X> tag and ending with the ">" character of the closing </258X> tag. The checksum follows immediately after the ">" character of the closing </258X> tag.

The digest provides a 128-bit checksum of the 258X file contents. The MD5 signature must be base64 encoded (see IETF RFC 1421 for the base64 algorithm) to convert the MD5 signature to a US-ASCII, base64 string. An end of line character will indicate the end of the base64 encoded MD5 signature.

3.1.3 File extension

The file extension for a 258X file is .cvg.

3.1.4 File remarks

The 258X format permits file remarks using the standard XML commenting notation. They are only to be used to support debugging software. A parser may ignore and discard remarks when reading a 258X file. File remarks are never to be used to represent design or manufacturing information.

3.1.5 Character set definition

The XML standard uses the Unicode character set. This character set covers the characters used in hundreds of written languages. The XML standard allows several of the Unicode encoding formats to be used in an XML file. IPC-2581 through IPC-2588 requires the use of the UTF-8 character encoding of the Unicode character set. Although comments and user assigned names may be in any language of choice, all qualified names or enumerated string names **shall** be in English only.

3.2 Data organization and identification rules

The 258X standards use a namespace mechanism for XML instance files that is similar to the XML namespace mechanism that was created for managing XML meta-data namespaces. The instance file namespace mechanism prevents collisions between the names used by the different products within a single file. This partitioning of namespaces is necessary because any of the 258X files may contain information describing an arbitrary collection of products. (Boards, assemblies, or panels that are products allowed in an IPC-258X file.) For example, a file could contain descriptions for building multiple electronic assemblies that are manufactured on separate panels. This mechanism also prepares the way for a distributed database of 258X design data in which the data can be trusted to be universally unambiguous.

3.2.1 Naming elements within a 258X file

The capability of Unique namespaces was created to allow a panel to be defined in the single 258X file that contains multiple unique boards. Since two boards may reuse the same identifier, e.g. "U1", "R1", it must be possible to separate names in the file into namespaces. The 258X namespace implementation borrows the notation used by XML namespaces and makes the 258X standard format consistent with conventional XML usage.

There are two types of names used to name top-level objects (element instances) in a 258X file. The first type of name is a `qualifiedName` type. This type includes a prefix in the name that corresponds to a namespace within the 258X file. The prefix and the globally unique identity of the `Namespace` are declared in the `Namespace` element. The second type of name is a `shortName` type. This type is

required to be unique within the 258X file. The syntax restrictions on short names and qualified names assure that all names will be unique as top-level names within 258X file.

3.2.2 The use of XML elements and types

A comprehensive overview of XML Schema can be found in the W3C XML Schema Primer. This section briefly describes the decisions that were made in the development of the 258X schema. Reviewing the Primer is recommended prior to reading this section.

The XML Schema defines a namespace mechanism that can be used when defining element names. The W3C also provides a set of general purpose element and attribute types, such as xsd:string, xsd:double, and xsd:datetime. The 258X format uses these standard types, however the documentation of the 258X standard has been defined without the use of a namespace prefix for element names within a 258X file.

Each of the schema elements has a prefix, "xsd:", which is associated with the XML Schema namespace through the declaration, xmlns:xsd="http://www.w3.org/2000/08/XMLSchema", that appears in the schema element. The prefix xsd: is used by convention to denote the XML Schema namespace, although any prefix can be used. The same prefix, and hence the same association, also appears on the names of built-in simple types, e.g. xsd:string. The purpose of the association is to identify the elements and simple types as belonging to the vocabulary of the XML Schema language rather than the vocabulary of the schema author.

In XML Schema, there is a basic difference between complex types that allow elements in their content and may carry attributes, and simple types that cannot have element content and cannot carry attributes. There is also a major distinction between definitions that create new types (both simple and complex), and declarations that enable elements and attributes with specific names and types (both simple and complex) to appear in document instances.

New complex types are defined using the `complexType` element and such definitions typically contain a set of element declarations, element references, and attribute declarations. The declarations are not themselves types, but rather an association between a name and constraints that govern the appearance of that name in documents governed by the associated schema. Elements are declared using the "element," and attributes are declared using the "attribute."

3.2.3 Attribute base types (governing templates)

The attribute basic types (SimpleTypes) provided by XML Schema are defined by the W3C. They are easy to distinguish from the IPC-258X types because the W3C type is always prefixed with "xsd:". The W3C datatypes are defined in http://www.w3.org/2000/10/XMLSchema (XML Schema Part 2).

Table 2 defines those W3C basic types that are used to define attributes in the 258X schema. The xsd:string type is constrained to create specific base types for special purpose strings, such as `qualifiedName` and `shortName`. The rules for special number types and the date format are also defined. Table 3 defines those basic types that have been standardized for use within the IPC-258X format.

Table 2 Governing template basic types defined by W3C

xsd:string	A W3C standard data type for a Unicode character string. The characters are from the UTF-8 character set as defined in http://www.ietf.org/rfc/rfc2279.txt.
xsd:double	A W3C standard data type for a binary floating-point number. The W3C definition of xsd:double is in http://www.w3.org/TR/xmlschema-2/. The xsd:double is a number where the value can be positive, negative, integer or floating point, with at least 7 digits of precision. Numbers are assumed to be positive but can be explicitly designated as positive by preceding the number with a '+' (ASCII decimal 43) character. Negative numbers must be explicitly designated as negative by a preceding '–' (ASCII decimal 45) character. An internal representation of an IEEE double precision floating-point number is assumed. This range of values for IEEE doubles is defined as 3.4x10-38 ≤ value ≤ 3.4x10+38. The format for representing a double is the same as the format used in the computer languages C, Perl, Python, or TCL. For example, all the following are legal numbers: 1.005 ; 0.01; .01; -2.334e-33; .224e-2
xsd:nonNegativeInteger	A W3C standard data type for non-negative integer numbers. The W3C definition of xsd:nonNegativeInteger is in http://www.w3.org/TR/xmlschema-2/. The range of values allowed are 0 ≤ value ≤ 2147483647 (the non-negative values that fit in a 32 bit signed integer).
xsd:positiveInteger	A W3C standard data type for positive integer numbers. The W3C definition of xsd:positiveInteger is in http://www.w3.org/TR/xmlschema-2/. The range of values allowed are 1 ≤ value ≤ 2147483647 (the positive values that fit in a 32 bit signed integer).
xsd:dateTime	The W3C standard data type for the current date and time is xsd:dateTime. (See http://www.w3.org/TR/NOTE-datetime-970915.html.) The following formats from the W3C specification are recommended for 258X files: Complete date plus hours, minutes and seconds: YYYY-MM-DDThh:mm:ssTZD (e.g. 1997-07-16T19:20:30.4536+01:00) Complete date plus hours, minutes, seconds and a decimal fraction of a Second: YYYY-MM-DDThh:mm:ss.sTZD (e.g. 1997-07-16T19:20:30.45+01:00) where: YYYY = four-digit year MM = two-digit month (01=January, etc.) DD = two-digit day of month (01 through 31) Hh = two digits of hour (00 through 23) (am/pm NOT allowed) Mm = two digits of minute (00 through 59) Ss = two digits of second (00 through 59) S = one or more digits representing a decimal fraction of a second TZD = time zone designator (Z or +hh:mm or –hh:mm)
xsd:anyURI	A W3C standard data type for hyperlinks. The W3C definition of xsd:anyURI is in http://www.w3.org/TR/xmlschema-2/.
xsd:unsignedByte	The W3C standard for an unsigned byte (an unsigned 8 bit integer with a value between 0-255.) The W3C definition of xsd:unsignedByte is in http://www.w3.org/TR/xmlschema-2/.
xsd:base64Binary	The data is encoded using base64. (see IETF *RFC 1421* for the base64 algorithm and http://www.w3.org/TR/xmlschema-2/#base64Binary)

Table 3 Governing template basic types defined by IPC

qualifiedName	The qualifiedName data type is a data type defined for the 258X series. The type is a restricted xsd:string data type where the pattern of the string must match the regular expression "[a-zA-Z][a-zA-Z0-9_-]*:.+". The definition of the qualifiedName data type is: <xsd:simpleType name = "qualifiedName"> <xsd:restriction base = "xsd:string"> <xsd:pattern value = "[a-zA-Z][a-zA-Z0-9_-]*:.+"/> </xsd:restriction> </xsd:simpleType> An example of a string that matches the pattern is: "prefix:name". The "prefix" is a Namespace name. The "name" is the name of an object within the Namespace.
nonNegativeDouble	The nonNegativeDouble data type is defined for the 258X series. The type restricts an xsd:double to positive numbers, inclusive of 0. The non-negative range of values for IEEE doubles is defined as $0.0 \leq value \leq 3.4x10^{38}$.
shortName	The shortName data type is a data type defined for the 258X series. The type is a restricted xsd:string data type where the pattern of the string must match the regular expression "[a-zA-Z][a-zA-Z0-9_-]*". The xsd definition of the shortName data type is: <xsd:simpleType name = "shortName"> <xsd:restriction base = "xsd:string"> <xsd:pattern value = "[a-zA-Z][a-zA-Z0-9_-]*"/> </xsd:restriction> </xsd:simpleType> An example of a string that matches the pattern is "bob_24"

3.2.3.1 Qualified name convention

The IPC-258X file supports two types of qualified names. One is a basic qualifiedName; the second is a complete qualifiedName as shown in Table 3.

A basic qualifiedName is composed of at least one letter, followed by any number of letters, numbers, underscores, or hyphens. To form a complete qualifiedName, one can optionally prefix a basic qualifiedName with a colon delimited path, where each step along the path is constructed the same way as the basic qualified name. This permits sorting of sort names into a hierarchy (see Table 3).

Examples of basic qualified names are:

"KarenSingleBoard"
"MultilayerStrategy"
"StandardPrimitiveShapes"

Examples of complete qualified names are:

"Set1:KarenSingleBoard"
"Set1:MultilayerStrategy"
"Set1:StandardPrimitiveShapes"

3.2.4 Coordinate system and transformation rules

Any geometry defined in a 258X file is defined in a Cartesian coordinate system. The x coordinates become more positive going from left to right (west to east). The y coordinates become more positive going from bottom to top (south to north). The primary side (TOP) of the board, coupon, or panel is in the x-y plane of the coordinate system with the primary side facing up.

The illustration in Figure 2 provides a perspective drawing of a board and a coordinate system. Each product in a 258X file is defined relative to a local coordinate system for the product. The point of origin of the product is located at (0,0) in the local coordinate system.

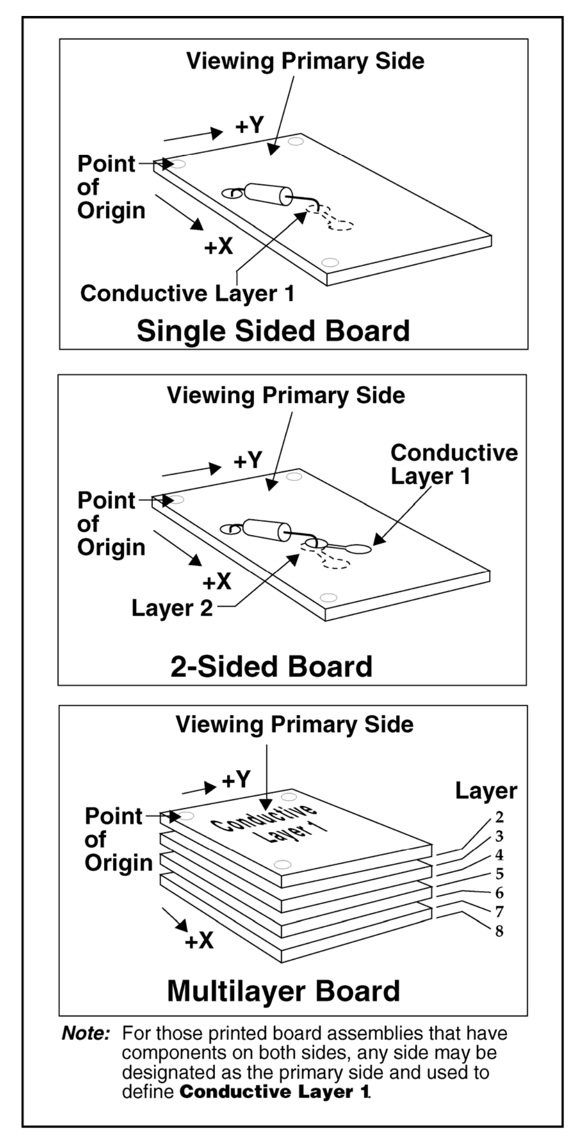


Figure 2 Printed board viewing

3.3 Transformation characteristics (Xform)

The `Xform` element defines a transformation that may be used throughout this specification to define a modification of the original stored data in the Dictionaries, the location and orientation of physical features. `Features`, `Shapes`, `Primitives` or other graphics in the file may manipulated relative to their local Cartesian coordinate system by the values set in the transform. The `Xform` element can define a modification of the pre-defined feature's point of origin, and then apply rotation, mirroring, scaling and location (x and y) of the image.

The units of measure are defined in the `CadHeader` as an attribute that describes the details of all the features in the `Ecad` section.In addition, units of measure are also defined in each of the Dictionaries that contain graphical information. These are `DictionaryStandard`, `DictionaryUser`, `DictionaryFont`, and `DictionaryLineDesc`. When a pre-define image from one of the dictionaries is used in the `Ecad` section, the units of measure must match.

The order of the transformation **shall** always follow the order of the fields in the description. This would be to 1) modify the origin; 2) apply rotation; 3) mirror image; and 4) scale.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated.	0-1
xOffset	double	The x offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
yOffset	double	The y offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
rotation	nonNegativeDouble Type	Defines the rotation of a shape about the local origin in degrees. Positive rotation is always counter-clockwise as viewed from the board TOP (primary side). Degree accuracy is expressed as a two place decimal i.e., 45.15; 62.34	0-1
mirror	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the image is mirrored; FALSE indicates that it is not.	0-1
scale	scaleType	An attribute that defines a “double” dimension whose minExclusiveValue=0.0 representing the multiplication factor of all x and y dimensions. The scale factor does not apply to angular values.	0-1

3.3.1 The x and y Offset attributes

The `xOffset` and `yOffset` attributes are of type xsd:double. They define the x and y offset of a shape relative to the origin of a Cartesian coordinate system. The definition of shapes can be nested and the x and y attributes are always interpreted relative to the local coordinate system of the shape to which the transformation applies. The default value for x and y is 0.0.

3.3.2 The rotation attribute

The `rotation` attribute is of type `nonNegativeDouble` that defines the rotation of a shape about the local origin. The interpretation of the value is set globally in the file to units of degrees. The `Units` element in the `Ecad Header` element specifies the units of measure. The range of the rotation parameter for DEGREES is 0.00 to 360.00 expressed as a `nonNegativeDouble` with an accuracy of a two place decimal. Positive rotation is always counter-clockwise as viewed from the board TOP (primary side), even if the component that is being rotated is on the board BOTTOM (secondary side). Rotation defaults to 0.0, and can be applied to text, or any physical shape.

3.3.3 The mirror attribute

The `mirror` attribute is of data type `boolean`. This type is an enumerated string indicating TRUE or FALSE. The default value for MIRROR is FALSE. When mirror is set to TRUE it indicates that all x dimensions are set to a –x value. The proper interpretation of the mirror and rotate attributes are shown in Figure 3. The example shows a unique artwork (14-pin DIP device) placed on the top and bottom of a board at 90.00° rotations.

3.3.4 The scale attribute

The `scale` attribute is of data type `scaleType`. The `scale` attribute is a "double" that must have a value greater than zero. All x and y dimensions of a geometry are multiplied by the scale attribute. The scale factor does not apply to angular values. The default value is 1.0.

3.3.5 The x and y Location attributes

The `xLocation` and `yLocation` attributes are of type xsd:double. They define the x and y position where a feature, component, text or other shape is placed. The `xLocation` and `yLocation` coordinate positions a shape by its original origin or its modified origin (x and y Offset) relative to the origin of the image upon which the feature, component etc. is to be located. Mirroring, rotating, and scaling may all apply to the location of the shape as indicated by the `Xform`.

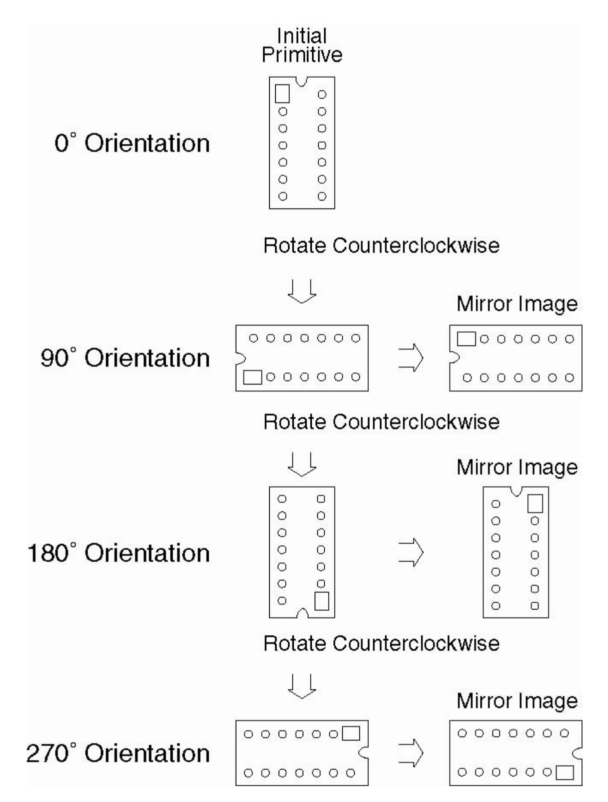


Figure 3 Mirror and Rotation Diagram

3.4 Substitution groups

The IPC-2581 uses the concept of substitution within the XML schema. Various groups of elements have been identified in the body of the standard and have been designated as having a specific focus or purpose. Within the schema, these substitution groups are provided with a name. When a group exists and if they are required according to the instances of the schema, it is mandatory that the substitution name be replaced by one of the acceptable descriptions identified within the group.

Often a schema needs to specify that one of several different XML Elements can be used with equal validity. For example, in every case where a `Triangle` can be used, it is also permissible to use a `Diamond`, `Hexagon`, `Octagon`, `Oval`, or one of several others: even though these shapes are quite different, they are equivalent as far as the schema is concerned. IPC-2581 handles this by using "substitution groups."

A substitution group consists of two types of elements: a “head”, and elements which may substitute for the head. Furthermore, when the head is denoted as ABSTRACT, the substitution is required, rather than optional. In IPC-2581, the heads of all substitution groups are ABSTRACT. Thus, it means that a valid instance document is not allowed to contain a `StandardPrimitive` element, but instead, (where `StandardPrimitive` is called for in the schema) a `Triangle`, `Diamond`, `Hexagon`, etc. must be used.

It should be noted that the head of one substitution group may be used within a different substitution group. As an example, the `StandardPrimitive` element is part of the `StandardShape` substitution group, which in turn is part of the `Feature` substitution group. This means that a `Triangle`, `Diamond`, `Hexagon`, etc may be used wherever a `Feature` or `StandardShape` is called for, as well as wherever a `StandardPrimitive` is called for.

IPC-2581 features several dictionaries that permit specifying some type of information (such as a `StandardPrimitive` or a `LineDesc`) one time, and to reuse that definition as often as necessary. Some substitution groups in IPC-2581 are present to enable specifying either a dictionary entry or the same kind of information defined in specific detail within the body of the file. Any predefined image contained in the Dictionaries must have a unique “id”. It is the “id” name that is used to instantiate information from any of the dictionaries.

There are 13 substitution groups within the IPC-2581 schema. These are shown in the following table.

- SubstitutionGroups
  - Attribute
  - ColorGroup
  - Feature
  - Fiducial
  - FirmwareGroup
  - FontDef
  - LineDescGroup
  - PolyStep
  - Simple
  - StandardPrimitive
  - StandardShape
  - UserPrimitive
  - UserShape

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Attribute	ABSTRACT	A substitution group that permits the substitution of the `Attribute` element when it is a child of the parent `Component`, `LogicalNet`, `Set`, or `Step` elements.	4
ColorGroup	ABSTRACT	A substitution group that permits the substitution of the `Color` element when it is a child of the parent `FinishType`, `Set`, or `Text` Elements.	3
Feature	ABSTRACT	A substitution group that permits the substitution of the `Feature` element when it is a child of the parent `Set` element.	1
Fiducial	ABSTRACT	A substitution group that permits the substitution of the `Fiducial` element when it is a child of the parent `Set` element.	1
FirmwareGroup	ABSTRACT	A substitution group that permits the substitution of the `FirmwareGroup` element when it is a child of the parent `Firmware` element.	1
FontDef	ABSTRACT	A substitution group that permits the substitution of the `FontDef` element when it is a child of the parent `EntryFont` element.	1
LineDescGroup	ABSTRACT	A substitution group that permits the substitution of the `LineDescGroup` element when it is a child of the parent `Outline`, `Polyline`, or `Set` elements.	3

PolyStep	ABSTRACT	A substitution group that permits the substitution of the PolyStep element when it is a child of the parent Polyline or Polygon elements.	2
Simple	ABSTRACT	A substitution group that permits the substitution of the Simple element when it is a child of the parent DfxMeasurement, Glyph, or Slot elements.	3
StandardPrimitive	ABSTRACT	A substitution group that permits the substitution of the StandardPrimitive element when it is a child of the parent EntryStandard element.	1
StandardShape	ABSTRACT	A substitution group that permits the substitution of the StandardShape element when it is a child of the parent LayerPad or Pad elements.	2
UserPrimitive	ABSTRACT	A substitution group that permits the substitution of the UserPrimitive element when it is a child of the parent EntryUser element.	1
UserShape	ABSTRACT	A substitution group that permits the substitution or classification of a higher level substitution group. The UserShape element may be used to further classify Feature. In so doing, UserShape can be substituted by a UserPrimitive or UserPrimitiveRef.	0

3.4.1 Attribute

The Attribute group consists of various identifiers that may be used within the body of the IPC-2581 standard. Attributes are optional and are used within the Component, LogicalNet, Set, and Step elements. Attributes contain legacy data that has not yet become a more formal part of IPC-2581.

The use of attributes within the 2581 file should be used with caution since their purpose is to classify a unique condition. Thus, all other data under the umbrella of the parent element that references the attribute would need to reflect the identical unique condition identified by the attribute.

The long range intention is to deprecate all Attributes and to incorporate their information elsewhere in IPC-2581 files. There are five kinds of standard Attributes that hold different types of data, and a NonstandardAttribute which can contain any type of data. The standard attributes are constrained to have specific names.

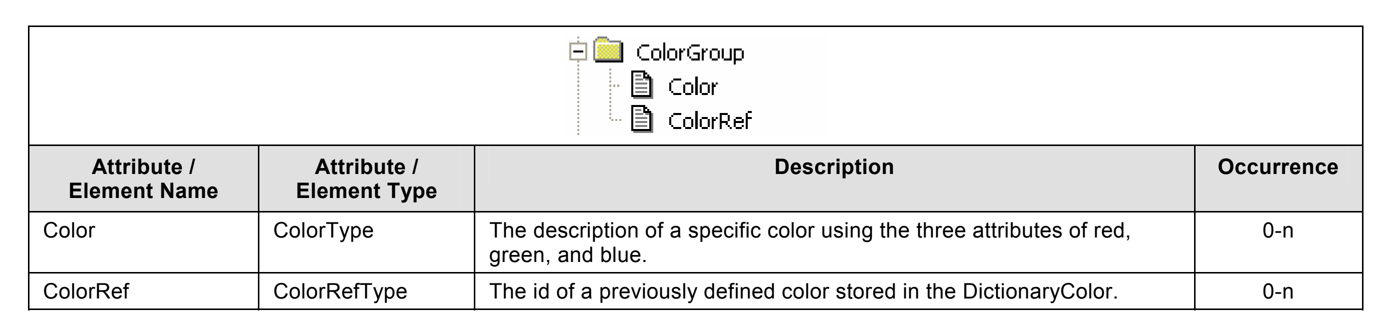
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
		Attribute BooleanAttribute DoubleAttribute IntegerAttribute NonstandardAttribute OptionAttribute TextAttribute	
BooleanAttribute	ABSTRACT	An element of type BooleanAttributeType that can subsitute for an Attribute element. A BooleanAttributeType has a value of type xsd:Boolean, and a name of enumerated type booleanAttributeName. The values for bolleanAttributeName are: smd | gold_plating | n_electric | nomenclature | tear_drop | pattern_fill | drill_noopt | foot_down | et_align | full_plane | out_orig | net_point | test_point | imp_line | non_tp | patch | shave | mount_hole | tooling_hole | is_capped | lpol_surf | critical_net | critical_tp | orbotech_plot_stamp | skip_indicator | out_mirror | lpol_done | cu_base | out_drill_full | out_drill_optional | out_rout_optional | array_with_rotation | out_break | out_scale | break_away | center_fiducial | comp_ign_spacing | no_tp_under | no_hole_under | no_trace_under | no_copper_shape_under | no_uncap_via_under | no_text_under | no_fiducial_check | thvpad_required | label_clearance | guard_comp | needs_guarding | ind_orient_req | is_burried | is_shadowed | is_wirebonded | spo_shape_stretch | toep_nochk_o_side | no_pop | comp_ignore | hp3070_test | drc_bend_keepout | drc_board | drc_mech | drc_etch_lyrs_all | drc_comp_keepin | drc_tp_keepin | drc_route_keepin | drc_comp_keepout | drc_tp_keepout | drc_trace_keepout | drc_pad_keepout | drc_plane_keepout | drc_via_keepout | drc_route_keepout | drc_comp_height | vcut | hatch | hatch_border | hatch_serrated_border | dxf_dimension	0-n
DoubleAttribute	ABSTRACT	An element of type DoubleAttributeType that can subsitute for an Attribute element. A DoubleAttributeType has a value of type xsd:double, and a name of enumerated type doubleAttributeName. The values for doubleAttributeName are: pitch | string_angle | spacing_req | board_thickness | out_x_scale | out_y_scale | out_comp | eda_layers | et_adjacency | layer_dielectric | fill_dx | fill_dy | image_dx | image_dy | local_fiducial_dist | comp_height | comp_htol_plus | comp_htol_minus | comp_weight | spo_shape_rotate | spo_move_center | spo_w_val | spo_w_fact | spo_h_val | spo_h_fact | spo_s_val | spo_s_fact | spo_p_val | spo_p_fact | toep_spacing_req | hp3070_tol_pos | hp3070_tol_neg | hp3070_hi_value | hp3070_lo_value | hp3070_seriesr | gencad_device_ptol | gencad_device_ntol | drc_max_height | drc_min_height | net_length_min | net_length_max | dpair_gap | eclass_voltage_swing | eclass_impedance | eclass_rise_time | eclass_min_stub_length | eclass_max_stub_length | min_line_width | ar_pad_drill_top_min | ar_pad_drill_top_max | ar_pad_drill_inner_min | ar_pad_drill_inner_max | ar_pad_drill_bottom_min | ar_pad_drill_bottom_max | ar_sm_pad_top_min | ar_sm_pad_top_max | ar_sm_pad_bottom_min | ar_sm_pad_bottom_max | ar_sm_drill_top_min | ar_sm_drill_top_max | ar_sm_drill_bottom_min | ar_sm_drill_bottom_max	0-n

IntegerAttribute	ABSTRACT	An element of type IntegerAttributeType that can subsitute for an Attribute element. An IntegerAttributeType has a value of type xsd:integer, and a name of enumerated type integerAttributeName. The values for integerAttributeName are: drill_flag | rout_chain | rout_flag | pilot_hole | out_flag | extended | feed | speed | cut_line | aoi_drcu | aoi_drbm | aoi_cpcu | aoi_cpbm | aoi_value | orig_surf | eda_dimension_id | output_dcode | design_origin_x | design_origin_y | out_drill_order | out_rout_order | num_local_fiducials | src_orientation | rot_correction | drc_min_space | drc_min_width | drc_add_rad | eclass_max_via_count | testpoint_count	0-n
NonstandardAttribute	ABSTRACT	An element of type NonstandardAttributeType that can subsitute for an Attribute element. A NonstandardAttributeType has a name of type xsd:string, a value of type xsd:string, and a type cadPropertyType. The cadPropertyType specifies how to interpret the value. The values for cadPropertyType are: DOUBLE | INTEGER | BOOLEAN | STRING	0-n
OptionAttribute	ABSTRACT	An element of type OptionAttributeType that can subsitute for an Attribute element. An OptionAttributeType has a value of enumerated type optionValue, and a name of enumerated type optionAttributeName. The values for optionAttributeName are: drill | via_type | comp | drill_stage | drill_sr_zero | pad_usage | primary_side | out_angle | out_polarity | layer_hdi_type | fs_direction_top | fs_direction_bottom | smt_direction_top | smt_direction_bottom | viacap_layer | wheel_type | comp_type | comp_type2 | comp_mount_type | comp_polarity | otherside_keepout | spo_w_mode | spo_h_mode | spo_s_mode | spo_p_mode | drc_assembly_lyrs | sip The values of optionValue are: plated | non_plated | via | drilled | laser | photo | none | right | left | 1 | 2 | 3 | toeprint | g_fiducial | l_fiducial | tooling_hole | Top | Bottom | 0.0 | 90.0 | 180.0 | 270.0 | Positive | Negative | Buildup | Core | Left2Right | Top2Bottom | Right2Left | Bottom2Top | Both | None | Gerber | Tools | axial | bga | cbga | cob | dip | discrete | discrete402 | discrete603 | label | pga | pihconn | pihmisc | plcc | pqfp | printed | qfp | radial | sip | smtconn | smtmisc | socket | soic | soj | sop | sot | tab | tqfp | tsoic | tsop | axial-large | csp | dip300 | dip600 | discrete | discrete201 | electro-mech | flipchip | lcc | lqfp | pfconn | pga | pihconn-inline | pihconn-rt-angle | pih-polar | radial-tall | smtelect-mech | smtmixedconn | smtpolar | solderable-mech | sop-ssop | tsop-tssop | reserved47 | reserved48 | reserved49 | reserved50 | reserved51 | reserved52 | reserved53 | reserved54 | reserved55 | reserved56 | reserved57 | reserved58 | reserved59 | reserved60 | reserved61 | reserved62 | reserved63 | reserved64 | reserved65 | reserved66 | reserved67 | reserved68 | reserved69 | reserved70 | reserved71 | reserved72 | reserved73 | reserved74 | reserved75 | reserved76 | reserved77 | reserved78 | reserved79 | reserved80 | reserved81 | reserved82 | reserved83 | reserved84 | reserved85 | reserved86 | reserved87 | reserved88 | reserved89 | reserved90 | reserved91 | reserved92 | reserved93 | reserved94 | reserved95 | reserved96 | reserved97 | reserved98 | reserved99 | reserved100 | Other | SMT | THMT | PRESSFIT | polarized | non_polarized | full_area | pins_only | Distance | Factor | Value | Area | detected | repaired	0-n

TextAttribute	ABSTRACT	An element of type TextAttributeType that can subsitute for an Attribute element. A TextAttributeType has a value of type xsd:string, and a name of enumerated type textAttributeName. The values for textAttributeName are: bit | geometry | fiducial_rdlist | area_name | source_llayer | fiducial_name | string | color | customer | comment | technology | global_camtek_aoiset | drc_route_keepin_lyr | drc_comp_keepin_lyr | drc_tp_keepin_lyr | drc_route_keepout_lyr | drc_via_keepout_lyr | drc_trace_keepout_lyr | drc_plane_keepout_lyr | drc_pad_keepout_lyr | drc_comp_keepout_lyr | drc_comp_height_lyr | drc_tp_keepout_lyr | inp_file | eda_layers | out_name | assembly_proc_top | assembly_proc_bottom | all_eda_layers | fab_drc | hdi_drc | hdi_drc | spo_shape | user_bom_rev | machine_pkg | hp3070_device | hp3070_value | hp3070_type | hp3070_fail_msg | hp3070_common_pin | hp3070_contact_pin | hp3070_contact_pin | hp3070_comment | gencad_device_type | gencad_device_style | gencad_device_value | drc_ref_des | drc_etch_lyrs | drc_etch_lyrs_bit | cad_part_override | diff_pair | net_type | electrical_class | eclass_individual_parallel_min_jog_list | eclass_individual_parallel_max_length_list | eclass_individual_parallel_dist_list | eclass_accumulative_parallel_max_length_list | eclass_accumulative_parallel_dist_list | station | variant_list | comp_variant_list | current_variant	0-n

3.4.2 ColorGroup

The `ColorGroup` substitution group consists of various colors that may be used within the body of the IPC-2581 standard. Color may be predefined and named in the `DictionaryColor`. `Color` is used by the `FinishType`, `Set`, or `Text` elements. It is referred to in the body of the file by its “Color ID” or by the three attributes that make up color (red, green, blue).



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Color	ColorType	The description of a specific color using the three attributes of red, green, and blue.	0-n
ColorRef	ColorRefType	The id of a previously defined color stored in the DictionaryColor.	0-n

3.4.3 Feature

The `Feature` substitution consists of two major substitution groups. Where `Feature` is called for, an instance must substitute a graphic allowed by either the `StandardShape` or `UserShape` substitution groups.

Feature
- StandardShape
- UserShape

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StandardShape	ABSTRACT	A substitution group that occurs in the IPC-2581 schema and permits the substitution of the `StandardShape` element when it is a child of the parent `LayerPad` or `Pad` elements.	0-n
UserShape	ABSTRACT	A substitution group that occurs in the IPC-2581 schema and permits the substitution or classification of a higher level substitution group. The `UserShape` element may be used to further classify `Feature`. In so doing `UserShape` can be substituted by a `UserPrimitive` or `UserPrimitiveRef`.	0-n

3.4.4 Fiducial

The `Fiducial` substitution group consists of three elements that may be used to replace the `Fiducial` element. When the `Fiducial` element is substituted, it **shall** be by either a `BadBoardMark`, `GlobalFiducial`, `GoodPanelMark`, or `LocalFiducial` pad type. The `Fiducial` elements contain an Xform and a substitution capability to a `StandardShape`. An optional `Pin` attribute allows reference to a component pin.

Fiducial
- BadBoardMark
- GlobalFiducial
- GoodPanelMark
- LocalFiducial

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
BadBoardMark	PadType	A set of Standard Shapes used as an aid to the board assembler by defining those boards in a panel that did not pass inspection or electrical test. The fiducial shape is positioned near each board in the assembly panel array and covered over to signify that the board is defective.	0-n
GlobalFiducial	PadType	A set of Standard Shapes used in the description, arrangement or positioning of a group of features on an individual board, assembly, or panel.	0-n
GoodPanelMark	PadType	A single Standard Shape used to define a panel where all boards on the panel are good. The fiducial is positioned once on the panel and enables reduction in inspection time.	0-n
LocalFiducial	PadType	A set of fiducials (usually a pair) used in the description and arrangement of features related to a specific component on a board, assembly, or panel which aide in the location/positioning process.	0-n

3.4.5 FirmwareGroup

The FirmwareGroup substitution group consists of the description element for the firmware that defines the data to be added to a component through the RefDes element of a particular BomItem. The information may be provided as a CachedFirmware element or as a reference to the firmware which has been stored and identified with an "id" in the DictionaryFirmware.

FirmwareGroup
- CachedFirmware
- FirmwareRef

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
CachedFirmware	CachedFirmwareType	An element that identifies the firmware needed for a particular component in the Bill of Material. The information is in a hexEncodeBinary format.	0-n
FirmwareRef	FirmwareType	An element that references CachedFirmware stored in the DictionaryFirmware through the callout of the firmware "id"	0-n

3.4.6 FontDef

The FontDef substitution group consists of the description of a font that is different than the standard Helvetica and which is contained in the DictionaryFont. Fonts in the dictionary have an "id" which is called out when a FontRef is instantiated. FontRef is used by the element Text, which is called for in SilkScreen and AssemblyDrawing. Text can also be substituted whenever a UserPrimitive, UserShape or Feature is called for.

FontDef
- FontDefEmbedded
- FontDefExternal

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FontDefEmbedded	FontDefEmbedded Type	A description of a font using individual characters that are defined in accordance with the Glyph element and are contained in the DictionaryFont. Fonts must be predefined and may not be instantiated as part of the data in the file.	0-n
FontDefExternal	FontDefExternal Type	A reference to an external font description through the instantiation of a URN. The font is named and the reference is contained in the DictionaryFont. The appropriate character set is defined by the URN. External Fonts must be predefined and may not be instantiated as part of the data in the file.	0-n

The term "Uniform Resource Name" (URN) refers to the subset of URI that are required to remain globally unique and persistent even when the resource ceases to exist or becomes unavailable. A URI can be further classified as a locator, a name, or both. The term "Uniform Resource Locator" (URL) refers to the subset of URI that identify resources via a representation of their primary access mechanism (e.g., their network "location"), rather than identifying the resource by name or by some other attribute(s) of that resource.

3.4.7 LineDescGroup

The LineDescGroup substitution specifies the LineWidth and LineEnd characteristics of any feature that requires that definition. Line descriptions are a part of the Outline, Polyline and Set element definitions. The substitution is also instantiated by the substitution group Simple which calls for Arc, Line, Outline and Polyline.

LineDescGroup LineDesc LineDescRef			
Attribute / Element Name	**Attribute / Element Type**	**Description**	**Occurrence**
LineDesc	LineDescType	An element that identifies the LineEnd and LineWidth characteristics	0-n
LineDescRef	LineDescRefType	A reference to a LineDesc that is contained in the DictionaryLineDesc and identified by its unique "id". The units for the dictionary are defined and must be consistent with the units of the CadHeader when referenced from the Ecad section.	0-n

3.4.8 PolyStep

The Polystep substitution consists of defining either a Line or an Arc as the continuation of a Polyline or Polygon description. The location information is interpreted as being the point to which the curve (Arc), or segment (Line) is drawn. The substitution may take place anywhere within the file where the elements Polyline and Outline occur. This action includes the dictionaries where graphic descriptions are predefined. The Units of measure must be consistent with the Units parameter of the three dictionaries where this substitution can take place; DictionaryStandard, DictionaryUser, and DictionaryFont.

PolyStep PolyStepCurve PolyStepSegment			
Attribute / Element Name	**Attribute / Element Type**	**Description**	**Occurrence**
PolyStepCurve	PolyStepCurveType	The continuation of the linear description of a Polyline or Polygon if the next portion to be defined is an arc. The end point of the arc is defined as well as the location of the radius. CounterClockwise is the default direction	0-n
PolyStepSegment	PolyStepSegmentType	The continuation of the linear description of a Polyline or Polygon if the next portion to be defined is a line segment. The end point of the line is defined.	0-n

3.4.9 Simple

The Simple substitution consists of defining an Arc, Line, Outline or Polyline. The Simple substitution is called for in the DfxMeasurement, Glyph, and Slot elements. Simple is also identified as a UserPrimitive, UserShape, or Feature and the four elements may be substituted when called for in conjunction with those descriptions. When predefined in the DictionaryUser, or DictionaryFont the Units must match those of the dictionary.

Simple
- Arc
- Line
- Outline
- Polyline

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Arc	ArcType	`Arc` elements are curves (defined by three sets of coordinates: `startX`, `startY`, `endX`, `endY` and `centerX`, `centerY`. The width of the arc is applied when the arc is instantiated or predefined.	0-n
Line	LineType	`Line` elements are individual line segments. The `lineWidth` and `lineEnd` conditions are defined when the line is instantiated or pre-defined. The `lineEnd` default is ROUND.	0-n
Outline	OutlineType	`Outline` has `Polygon` and `LineDesc` as children elements. The characteristics of the `Polygon` must be a closed shape. The point of origin of the shape is identified as the 0:0 coordinate. The element includes the start of the polygon definition (`PolyBegin`) and the appropriate number of PolySteps to complete the closed shape. The `lineWidth` is defined at a time when the `Outline` is instantiated or predefined.	0-n
Polyline	PolylineType	The `Polyline` element consists of a series of lines that define a particular grouping configuration. These line segments do NOT result in a closed shape, however they can be pre-defined and re-used as needed. The `lineWidth` and `lineEnd` of the `Polyline` are defined at the time the `Polyline` is instantiated or predefined.	0-n

3.4.10 StandardPrimitive

There are sixteen Standard Primitives defined in the IPC-2581 structure. Any of the primitive shapes may be a candidate for substitution when `StandardPrimitive` is called for in the schema. The names of the various shapes indicate their type; each has its attributes that identify the physical requirements. Any `StandardPrimitive` may be predefined, provided a unique “id”, and contained in the `DictionaryStandard`. All `StandardPrimitive` shapes are developed in accordance with their description requirements in the preferred orientation of this standard.

StandardPrimitive
- Butterfly
- Circle
- Contour
- Diamond
- Donut
- Ellipse
- Hexagon
- Moire
- Octagon
- Oval
- RectCenter
- RectCham
- RectCorner
- RectRound
- Thermal
- Triangle

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Butterfly	ButterflyType	A primitive shape (either ROUND or SQUARE) that has two quadrants of the Cartesian coordinate system removed (0 to 90° and 180 to 270°).	0-n
Circle	CircleType	A primitive shape that defines a round object where the circular shape consists of a diameter.	0-n
Contour	ContourType	A closed primitive shape that has as its children a polygon and optional cutout(s) The sequence of connected edges that form the polygon may be straight or circular.	0-n
Diamond	DiamondType	A primitive shape with four equal sides that are extended from its horizontal center to its vertical center. The lines converge into a point both horizontally and vertically. The overall description of the shape is controlled by the width (distance between vertical point) and the height (distance between horizontal point).	0-n
Donut	DonutType	A round, square, hexagon, or octagon shaped primitive consisting of an outer diamer and inner diameter that define physical characteristics of the donut.	0-n
Ellipse	EllipseType	An elliptical primitive shape that follows the standard ellipse characteristics and is defined by a width and height dimension, establishing the overall limits of the feature.	0-n
Hexagon	HexagonType	A six-sided primitive shape with all sides being equal in length and with all angles between adjacent sides being equal. The orientation of the Hexagon is with one of its points facing North. Only the dimension across the points is required.	0-n
Moire	MoireType	A series of circles, each consisting of a smaller diameter than the previous.The details of the `Moire` is defined by the number of rings, their center line spacing, and the ring width. The pattern may also contain a crosshair representing its point of origin. Restrictions apply so that `ringWidth` is smaller than `ringGap`.	0-n
Octagon	OctagonType	An eight-sided primitive shape with all sides being equal in length and with all angles between adjacent sides being equal. The orientation of the `Octagon` is with one of its points facing north. Only the dimension across the points is required.	0-n
Oval	OvalType	A rectangular primitive shape with a complete radius (180° arc) at each end. The limits of the feature are controlled by the length and width of the oval across the outer extremities.	0-n

RectCenter	RectCenterType	The characteristics of a rectangle defined by a width and height dimension consistent with a horizontal position on the Cartesian coordinate system. The center point is the point of origin and is used to locate the `RectCenter`. A "`square`" is a `RectCenter` with the width and height equal.	0-n
RectCham	RectChamType	A rectangle with one or more corners chamfered. The user has the option to define any of the corners as containing the chamfer as well as the chamfered dimensions. All chamfers (or opportunities for chamfers) must be identical in size.	0-n
RectCorner	RectCornerType	A constraining rectangular area (bounding box) that describes a rectangle consistent with a horizontal position on the Cartesian coordinate system. The point of origin is the lower left corner. A Square positioned by its corners is a `RectCorner` that is defined by having the X and Y offset be equal.	0-n
RectRound	RectRoundType	A rectangle with one or more corners rounded. The user has the option to define any of the corners as containing the radius as well as the radiused dimensions. All corners (or opportunities for corners) must be identical in size.	0-n
Thermal	ThermalType	A primitive shape consisting either of ROUND, SQUARE, HEXAGON, or OCTAGON configuration that historically defines the removal of material from a plane or conductive fill area in accordance to the shape attribute description.	0-n
Triangle	TriangleType	A primitive isosceles triangular shape that has two equal sides and a base. The feature is defined by a base and height dimension.	0-n

3.4.11 StandardShape

The `StandardShape` substitution group permits the substitution of any of the `StandardPrimitive` shapes in accordance with their individual descriptions. A predefined `StandardPrimitive` may also be instantiated by its unique "`id`" when the feature is contained in the `DictionaryStandard`. When a reference is made to the dictionary predefined primitive, the `Units` must match.

StandardShape
StandardPrimitive
StandardPrimitiveRef

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StandardPrimitive	ABSTRACT	A substitution group that permits the substitution of the `StandardPrimitive` element with any of the sixteen standard primitive types.	0-n
StandardPrimitiveRef	StandardPrimitive RefType	A reference to a predefined `StandardPrimitive`, contained in the `DictionaryStandard`. The reference is by its unique "id". The units of the referenced predefined primitive and the `Ecad` section where it is to be instantiated must match.	0-n

3.4.12 UserPrimitive

The `UserPrimitive` substitution group consists of any simple graphic feature (`Arc, Line`, `Outline or Polyline`), as well as `text` or `UserSpecial` shapes. The `UserSpecial` element is a collection of `Features` (which are any of the permitted graphics used in the 2581 file). `UserSpecial` permits the definition of logos, special targets, drawing formats or other graphics needed by a particular design. `UserPrimitives` can be predefined, assigned a unique "id" and contained in the `DictionaryUser`. The `DictionaryUser` defines the `Units` used to describe the graphic shapes.

UserPrimitive
Simple
Text
UserSpecial

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Simple	ABSTRACT	A substitution consists of defining an Arc, Line, Outline or Polyline. The Simple substitution is called for in the schema in DfxMeasurement, Glyph, and Slot elements and may be defined in any other graphics.	0-n
Text	TextType	The text element defines text strings, fonts, and the bounding box containing the text. Also included are Xform to position, mirror or rotate the text.	0-n
UserSpecial	UserSpecialType	The UserSpecial element has all the capabilities allowed by the standard. The characteristic uses the substitution group "Feature" and may develop any combination of graphical shapes.	0-n

3.4.13 UserShape

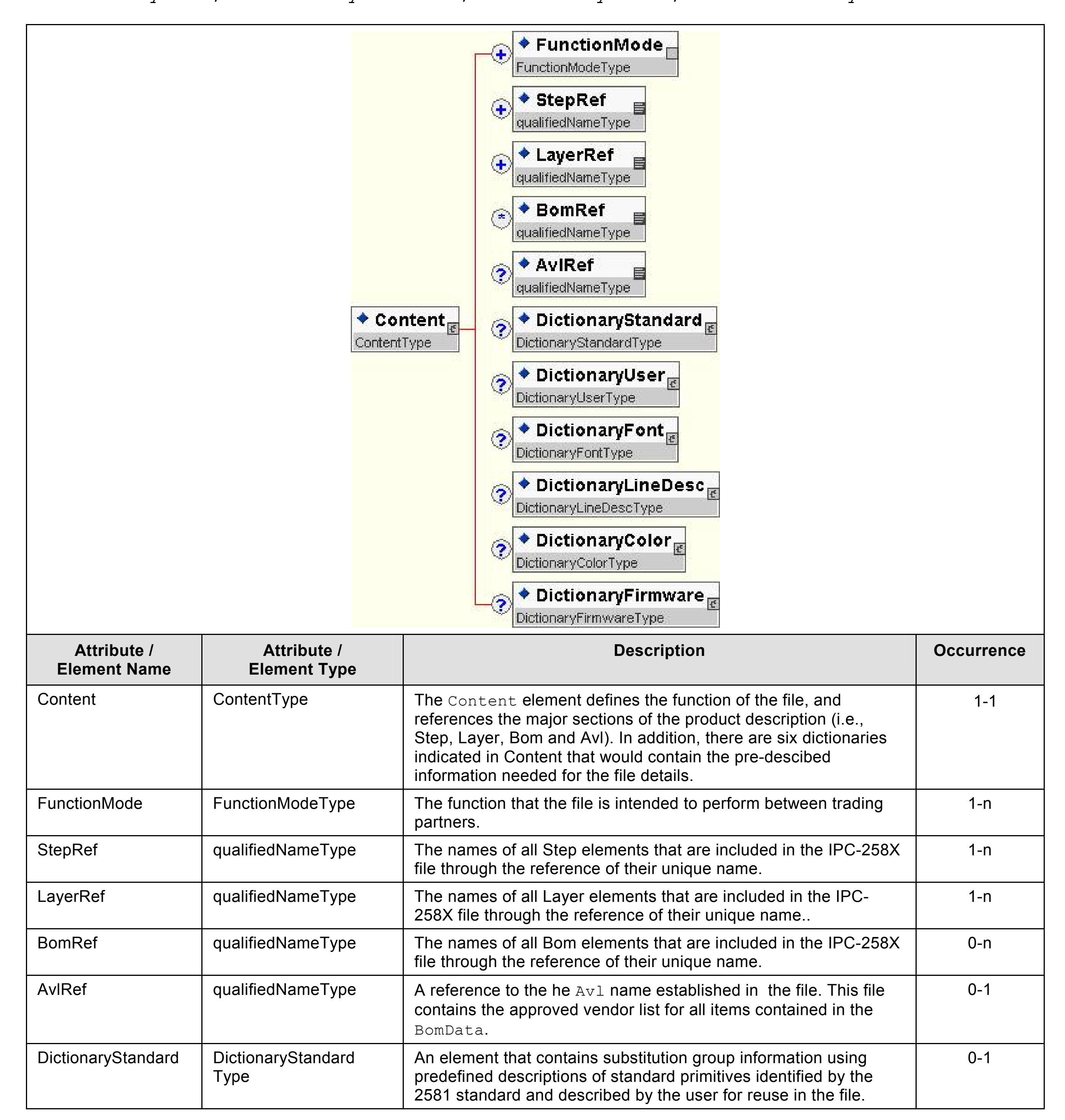
The UserShape substitution group permits the substitution of any of the UserPrimitive shapes in accordance with their individual descriptions. A predefined UserPrimitive may also be instantiated by its unique "id" when the feature is contained in the DictionaryUser. When a reference is made to the dictionary predefined primitive, the Units must match.

UserShape
UserPrimitive
UserPrimitiveRef

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
UserPrimitive	ABSTRACT	A substitution group that occurs in the IPC-2581 schema and permits the substitution of the UserPrimitive element with any of the user primitive description or types.	0-n
UserPrimitiveRef	UserPrimitiveRefType	A reference to a predefined UserPrimitive, contained in the DictionaryUser. The reference is by its unique "id". The units of the referenced predefined primitive and the Ecad section where it is to be instantiated must match.	0-n

4 CONTENT

The `Content` sub-element provides the information about the contents of the IPC-258X file. The `Content` schema identifies the depth and breadth of information in the file. The `Content` sub-elements include references to the `FunctionMode`, `StepRef`, `LayersRef`, `BomRef`, and `AvlRef` included in the file, plus six Dictionaries: `DictionaryStandard`, `DictionaryUser`, `DictionaryFont`, `DictionaryLineDesc`, `DictionaryColor`, and `DictionaryFirmware`.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Content	ContentType	The `Content` element defines the function of the file, and references the major sections of the product description (i.e., Step, Layer, Bom and Avl). In addition, there are six dictionaries indicated in Content that would contain the pre-descibed information needed for the file details.	1-1
FunctionMode	FunctionModeType	The function that the file is intended to perform between trading partners.	1-n
StepRef	qualifiedNameType	The names of all Step elements that are included in the IPC-258X file through the reference of their unique name.	1-n
LayerRef	qualifiedNameType	The names of all Layer elements that are included in the IPC-258X file through the reference of their unique name..	1-n
BomRef	qualifiedNameType	The names of all Bom elements that are included in the IPC-258X file through the reference of their unique name.	0-n
AvlRef	qualifiedNameType	A reference to the he `Avl` name established in the file. This file contains the approved vendor list for all items contained in the `BomData`.	0-1
DictionaryStandard	DictionaryStandard Type	An element that contains substitution group information using predefined descriptions of standard primitives identified by the 2581 standard and described by the user for reuse in the file.	0-1

DictionaryUser	DictionaryUserType	An element that contains substitution group information using predefined descriptions of user primitives identified by the 2581 standard and described by the user for reuse in the file.	0-1
DictionaryFont	DictionaryFontType	An element that contains substitution group information regarding font descriptions as predefined Glyphs or references to external URN's for character sets that differ from the Helvetica standard.	0-1
DictionaryLineDesc	DictionaryLineDesc Type	An element that contains substitution group information using line description criteria, predefined by the user for reuse in the file.	0-1
DictionaryColor	DictionaryColorType	An element that contains substitution group information using color description criteria, predefined by the user for reuse in the file.	0-1
DictionaryFirmware	DictionaryFirmware Type	An element that contains substitution group information using firmware description criteria, predefined by the user for reuse in the file.	0-1
The XML schema will have a restriction that requires the reference for `StepRef`, `LayerRef`, `BomRef`, and `AvlRef` be by the globally unique "name". The intent of the Content Element is to act as a table of contents for the 2581 file.			

4.1 Content: FunctionMode

The `FunctionMode` element defines the global mode of the file (see Table 4). There are five valid values for the `mode` attribute. These are:

FULL – everything in the IPC-2581 standard job is included

DESIGN – file carries mostly Design start or complete description

FABRICATION – file carries mostly Fabrication information

ASSEMBLY – file carries mostly Assembly information

TEST – file carries mostly testing information for bare board or assembly

Table 4 File Segmentation and Function Apportionment

Name	Full	Design			Fabrication			Assembly			Test		
		1	2	3	1	2	3	1	2	3	1	2	3
Hierarchical layer/stack instance files	Y	N	Y	N	N	N	N	N	N	N	N	N	N
Hierarchical conductor routing files	Y	N	Y	N	N	N	N	N	N	N	N	N	N
BOM (Components and Materials)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
AVL (Components and Materials)	Y	N	Y	Y	N	Y	Y	Y	Y	Y	N	N	Y
Component Packages	Y	Y	Y	Y	N	N	Y	Y	Y	Y	N	Y	Y
Land Patterns	Y	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y
Device Descriptions	Y	Y	Y	Y	N	N	N	N	N	Y	N	N	Y
Component Descriptions	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	Y	Y
Soldermask; Solder Paste Legend Layers	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Drilling and Routing Layers	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Documentation Layers	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Net List	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	N	Y
Outer Copper Layers	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Inner Layers	Y	N	N	Y	Y	Y	Y	N	Y	Y	N	N	Y
Miscellaneous Image Layers	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y
DFX Analysis	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Each FunctionMode has a specific purpose defined for the industry. The FunctionMode element has three attributes. The first is mode, which can be the enumerated strings of DESIGN, FABRICATION, ASSEMBLY, TEST and FULL. In many instances, the testing function is already included in fabrication and assembly modes consisting of bare board testing for fabrication, and in-circuit testing for assembly. Nevertheless, there are times when companies wish to outsource the testing activity. Therefore it is important to identify the various testing modes.

In order to define additional granularity, FunctionMode has a second attribute, level, that defines the data complexity needed for each of the mode condition. The attribute level is a positive integer however only the numbers 1, 2 or 3 are presently allowed since each mode has only three levels. When identifying FULL as the mode, the level should be set at 1. The levels encompass their own file details in order to identify that they are associated with an individual mode. Thus, the required file content for level 1 of the DESIGN mode is not the same as a level 1 for the ASSEMBLY mode.

The FunctionMode element has a third attribute. The attribute is comment which, as string data, permits the users of the 2581 file to enhance the FunctionMode descriptions with additional information.

4.1.1 FULL mode

The FULL mode identifier incorporates a total of fifteen functions. Each function is represented and available in the file. The order of the details in the file is not significant as several elements may be used to address any given function. Hierarchical padstack and route information reflects original design intent that may be altered in the representation of the flattened fabrication data. For FABRICATION and ASSEMBLY, flattened data **shall** be used.

4.1.2 DESIGN mode

The DESIGN mode consists of three levels of complexity. Each level performs a different function consisting of an original design starting from scratch to completed design that had already been converted to manufacturing data, or a completed design that is still in the CAD format structure. See IPC-2582 and IPC-2583 for sectional data descriptions.

4.1.3 FABRICATION mode

The FABRICATION mode consists of three levels of complexity. Each level describes information in a layered format, from very simplistic data to that where the customer has dictated very specific materials and material stack-up structures. See IPC-2584 and IPC-2588 for sectional data descriptions.

4.1.4 ASSEMBLY mode

The ASSEMBLY mode consists of three levels of complexity. Each level describes a concept of more complete information. The simplest level is mainly bill of material data as well as external copper layers. In its most complete form, the assembly information describes the component approved vendor listing for aliases and substitution in sufficient detail to ensure proper assembly. See IPC-2586 and IPC-2588 for sectional data descriptions.

4.1.5 TEST mode

The Test mode consists of three levels of complexity. Each level describes a specific function for testing information that must be contained within a file. In its simplest mode, the data describes information to allow bare board testing. In its most complex mode, there is information on in-circuit test, impedance control, and dielectric withstanding voltage conditions. See IPC-2585 and IPC-2587 for sectional data descriptions.

4.2 Function levels

The IPC-258X is limited to be organized as one of thirteen function levels. The level attribute, when associated with the mode attribute, defines the complexity and detail of the file content.

The `level` attribute consists of a positive integer and identifies complexity with respect to the characteristics for mode-DESIGN, mode-FABRICATION, mode-ASSEMBLY, and mode-TEXT. A mode-FULL consists of all the elements for an IPC-258X file and has only one (1) level value. For all other modes, the `level` attribute relates to the type of mode and is apportioned as one of three levels.

FunctionMode FunctionModeType — mode modeType — level positiveInteger — comment string

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FunctionMode	FunctionModeType	The function that the file is intended to perform between trading partners.	1-1
mode	modeType	An enumerated string, either FULL | DESIGN | FABRICATION | ASSEMBLY | TEST, that defines the type of mode that the file is intended to serve.	1-1
level	positiveInteger	A numerical value of 1, 2, or 3 used to define the complexity of the mode.	1-1
comment	string	Any appropriate comment to help clarify the intended use of the file.	0-1

4.2.1 FULL Mode Level 1

The FULL mode level 1 requirements are shown as follows. The characteristics represent the most complete state possible.

Layer Stack: Instances of multilayer structure at a single point site defining the characteristics that exist at a particular point including land description or reference, non-pad description or reference, thermal connections or reference, and holes (through-hole, buried, blind, and microvias). LayerStacks are for reference to the construction of the original design.

Conductor Route: Original CAD data files describing conductive patterns and features used to interconnect electronic components in accordance with the original schematic capture file and component library descriptions.

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a specific land pattern, a component package style, and a device if the component is electronic.

Masking Layer: Images for soldermask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of soldermask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.2 Design Levels

The Design Level requirements have a variety of element combinations. Each combination is identified by its `mode` and `level` in combination. There are three Design Level descriptions starting with Design Level 1, Design Level 2 and Design Level 3. The following sections show the content of each of the three design levels. It should be noted that when the elements that represent the design mode are available in any of the fabrication or assembly file structures, the information should be treated as original input and reference and can be used for analysis and checking, however ASSEMBLY and FABRICATION elements take precedence.

4.2.2.1 Design Level 1

This level represents the original OEM design as was used to lay out a PCB from the design schematic, layout design rules, and component information. The characteristics represent designing from scratch, taking OEM input and developing the board. Design Level 1 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components and their relation to their logical net description.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a specific land pattern, a component package style, and a device if the component is electronic.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of logical nets that includes the physical net points of the components, the location, side, as well as additional information required for bare board electrical testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the Analysis element.

4.2.2.2 Design Level 2

This level provides information that is used to modify an existing design using the original CAD data information since the changes impact the electrical characteristics that should be maintained. The

characteristics represent modifying a design where the Fabrication and Assembly file has been archived by the OEM. Design Level 2 requirements are shown as follows:

Layer Stack: Instances of multilayer structure at a single point site defining the characteristics that exist at a particular point including land description or reference, non-pad description or reference, thermal connections or reference, and holes (through-hole, buried, blind, and microvias). LayerStacks are for reference to the construction of the original design.

Conductor Route: Original CAD data files describing conductive patterns and features used to interconnect electronic components in accordance with the original schematic capture file and component library descriptions.

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a specific land pattern, a component package style, and a device if the component is electronic.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.2.3 Design Level 3

This information is used to modify an existing or archived design where the original hierarchical information was not maintained or may not be compatible with the design system. The characteristics represent modifying a design using the original CAD data information since the changes impact the electrical characteristics that should be maintained. Design Level 3 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a specific land pattern, a component package style, and a device if the component is electronic.

Masking Layer: Images for soldermask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of soldermask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.3 Fabrication Levels

The Fabrication Level requirements have a variety of element combinations. Each combination is identified by its `mode` and `level` in combination. There are three Fabrication Level descriptions starting with Fabrication Level 1, Fabrication Level 2 and Fabrication Level 3. The following sections show the content of each of the three fabrication levels.

4.2.3.1 Fabrication Level 1

This information represents single, double-sided, or multilayer PCB graphical data. There is no electrical connectivity or performance data included. This level replaces PCB fabrication Gerber data. This level presents the fabrication print notes and material construction information in a machine-readable ASCII file format. The level is for build to documentation instructions. Electrical testing is derived from the conductive images. The characteristics represent single or double sided boards, built to documentation. Fabrication Level 1 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Masking Layer: Images for soldermask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of soldermask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.3.2 Fabrication Level 2

This information represents single, double-sided, or multilayer PCB's where electrical connectivity or performance data is included. This replaces the PCB Gerber and IPC-D-356A. This level presents the fabrication print notes and material construction information in a machine-readable ASCII file format. The boards defined may include buried and blind vias with electrical opens and shorts testing and complete stack up definition. Fabrication Level 2 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Masking Layer: Images for soldermask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of soldermask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.3.3 Fabrication Level 3

This information represents single, double-sided, or multilayer PCB's where electrical connectivity, performance data, and embedded passive information is included. This file level replaces the existing PCB fabrication Gerber and IPC-D-356A data. This level presents the fabrication print notes and material construction information in a machine-readable ASCII file format. These descriptions represent complex printed boards intended to perform a circuit function. Also included is a complete description of core, prepreg and sometimes reinforcement. Fabrication Level 3 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Masking Layer: Images for soldermask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of soldermask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive (resistive or capacitive) material layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.4 Assembly Levels

The Assembly Level requirements have a variety of element combinations. Each combination is identified by its `mode` and `level` in combination. There are three Assembly Level descriptions starting with Assembly Level 1, Assembly Level 2 and Assemblyy Level 3. The following sections show the content of each of the three assembly levels.

4.2.4.1 Assembly Level 1

This information represents pure assembly. There is no Design for Manufacturing (DFM) analysis of the bare board only assembly functions. Parts are provided on a consignment basis, however an Approved Vendors List (AVL) is still required that includes the part number of parts in the consignment. There is no analysis of the data to improve the design. There are no added value services. The requirements are to build to print. Assembly Level 1 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, assembly, and test information.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a component package style, and a Bom item.

Masking Layer: Images for soldermask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of soldermask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.4.2 Assembly Level 2

The information provided represents assemblies that are to be built to print. Parts are procured by Electronic Manufacturing Services (EMS) companies. There is limited DFM analysis, Automated Optical Inspection (AOI), and Flying probe testing. Assembly Level 2 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a component package style, and a Bom item.

Masking Layer: Images for soldermask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of soldermask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.4.3 Assembly Level 3

This level of information represents a full service assembly process. This includes full Design for Excellence (DFX) and customer feed back. Procurement of parts is required as well as an analysis of component substitution. Customer contact provides design improvement recommendations. Full testing, including in-circuit, automatic optical inspection (AOI), Automatic X-ray Inspection (AXI), functional testing and some stress or burn-in testing is a part of this level. DFA can include assignment of parts to specific machines. Assembly Level 3 requirements are shown as follows.

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a component package style, and a Bom item.

Masking Layer: Images for soldermask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of soldermask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.5 Test Levels

TheTest Level requirements have a variety of element combinations. Each combination is identified by its `mode` and `level` in combination. There are three Test Level descriptions starting with Test Level 1, Test Level 2 and Test Level 3. The following sections show the content of each of the three test levels.

4.2.5.1 Test Level 1

This information provides testing of the bare board only. It includes opens and shorts, impedance control and dielectric withstanding voltage testing. Test Level 1 requirements are shown as follows:

Masking Layer: Images for soldermask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of soldermask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.2.5.2 Test Level 2

The information provided includes capability for inspection, manual or using automated equipment such as AOI and AXI. It does not include electrical testing. Test Level 2 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a component package style, and a Bom item.

Masking Layer: Images for soldermask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of soldermask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the Analysis element.

4.2.5.3 Test Level 3

The information available is for full electrical testing. It includes in-circuit as well as functional testing requirements and boundary scan (self test) analysis. Test Level 3 requirements are shown as follows:

Bom: Bill of Material information that describes, in sufficient detail, the component descriptions of the printed board, as well as the materials used for board fabrication, assembly, and test.

Avl: An approved vendor list for each item as defined by the OEM and modified accordingly by the board fabricator and the board assembler to reflect the materials and components used in the final electronic assembly.

Component Packages: Physical outlines of mechanical dimensions for electronic and mechanical components, their pins, (lands), and their relation to their logical net description.

Land Patterns: Combinations of lands used on outer layers that are grouped into a pattern so that they coincide with the mounting pins (IO's) of electronic or electromechanical components. The information is through a reference to the individual land for each pin of a device. Land patterns are for reference only to provide a grouping of lands related to a particular component.

Device Descriptions: Device characterization including the electronic or electromechanical part number, as well as its value, tolerance, and pin ID consisting of a name and function.

Component Descriptions: Consists of the components and their instances on the electronic assembly, including a reference to a component package style, and a Bom item.

Masking Layer: Images for soldermask on external layers of a printed circuit board (top and bottom) as well as legend marking to be incorporated on top of soldermask material.

Drilling Routing: Information on hole forming, either through mechanical drilling, laser ablation, or chemical mechanism and the relationship of the conductor routing layer.

Documentation Layers: Information on the details for finishes, tolerances, and other details necessary to complete the full disclosure of the printed board structure and/or assembly.

Net List: A list of physical nets that includes the physical net points, the location, side, as well as additional information required for bare board electrical testing.

Outer Conductive: External copper geometries and features used for electronic probing or component attachment. They may be defined as positive or negative.

Inner Layers: Image description for innerlayers of multilayered PCB's where the description indicates the conductive pattern as well as plated-through holes contained within a layerset. These characteristics are also used to describe embedded passive layers.

Image Layers: Miscellaneous image layers that may be extracted from the originating CAD system that provide supplementary details for either printed circuit board fabrication or printed circuit board assembly processes and testing.

Analysis: Any of the CAD data can have Design for Manufacturing processes run against it. The results of these are referenced in the `Analysis` element.

4.3 Content: StepRef

The reference to the names of all `Step` elements used in the description of the Printed Circuit Assembly (PCA), the unpopulated board or other related information (eg., documentation). In manufacturing, this basic `Step` is often step and repeated (nested) inside a larger step (called array, or sub-panel). This array step can be further nested into another step (called a production panel). The

Ecad element always contains at least one Step, but may contain several, some basic ones and others nesting previous steps.

The StepRef element, as it appears in the Content schema, references the job step's names and thus the various steps that are included in the IPC-2581 file. All the graphical data of a 2581 job are located inside steps that can be nested inside each other (PCB/Sub Panel/Panel, etc.). Steps are referenced in the Content schema (StepRef) as a qualifiedName that relates to the details in the Ecad schema.

StepRef
qualifiedNameType

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StepRef	qualifiedNameType	The unique names of all existing step elements contained within the file. This feature is a method of checking completeness in file transfer.	1-n

4.4 Content: LayerRef

Layers, as the name implies, are sheets of two-dimensional data that, when laid on top of each other, create the Printed Circuit Assembly (unpopulated PCB and components or other related information). The Layer element appears in the IPC-2581 file as a sub-element of the CadData element.

The LayerRef element, as it appears in the Content schema, references all the file Layerunique names included in the IPC-2581 file.

LayerRef
qualifiedNameType

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LayerRef	qualifiedNameType	The unique names of all existing layer elements contained within the file. This feature is a method of checking completeness in file transfer.	1-n

4.5 Content: BomRef

The BOM section describes the Bill of Materials for the board. A bill of materials is a list of all the different components, materials, mechanical parts, or programmable software used in the electronic product. Components are arranged by the OEMDesignNumber or an alternate; materials for board fabrication or component attachment are arranged by their appropriate identifier. Each part number has a list of attributes and is accompanied by a list of the various specific uses or locations on the electronic product, each with its unique name.

Each BomRef element, as it appears in the Content schema, references one of the potentially many Bom categories and the number of items included in each category in the IPC-2581 file.

◆ BomRef qualifiedNameType			
Attribute / Element Name	**Attribute / Element Type**	**Description**	**Occurrence**
BomRef	qualifiedNameType	The unique names of all BOM elements that are arranged by the category description contained as an attribute of each BomItem, e.g. ELECTRICAL | PROGRAMMABLE | MECHANICAL | MATERIAL. This feature identifies the specific number of BomItems as well as the category to which they pertain, and is a method of checking completeness in file transfer.	0-n

4.6 Content: AvlRef

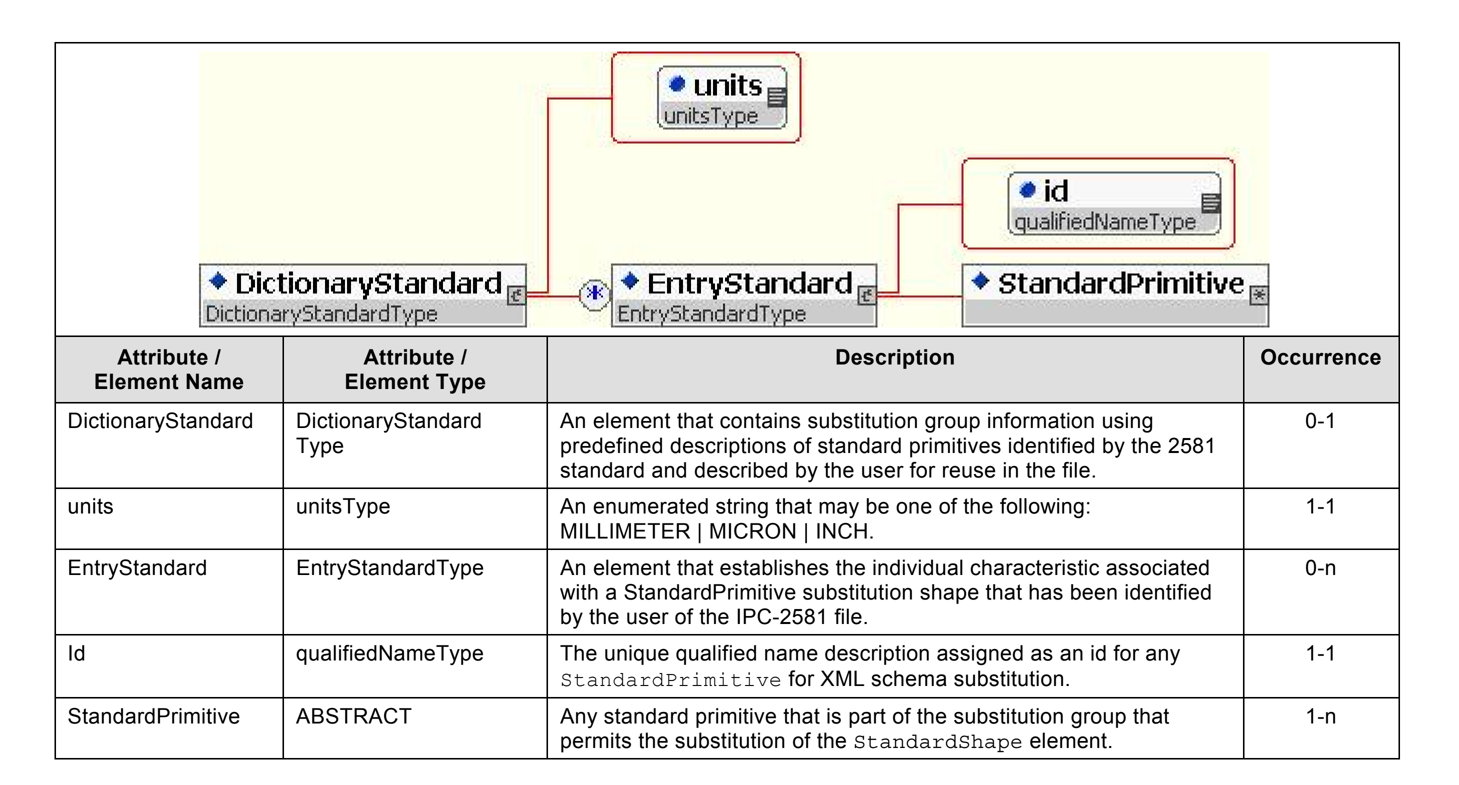
The Avl section describes the Approved Vendor Lists for the materials used to fabricate the board and the assembly. The BOM (bill of material) lists include all the different components to be used on the board, arranged by their appropriate part number, and material used to fabricate the board arranged by the part number of the material. There are also BOMs for the material used that are consumed by the fabrication and assembly processes. Each BOM has a corresponding list of approved vendors if the customer wishes to restrict the components and materials used for the electronic assembly to a specific supplier(s). There **shall** be only one Avl section in a 2581 file. It **shall** provide the names of each of the approved suppliers and **shall** correlate them with the BOM that contains the material/component descriptions.

The Avl is used by the customer, the fabricator and the assembler to coordinate the relationship with the bills of materials described in the IPC-2581 file.

◆ AvlRef qualifiedNameType			
Attribute / Element Name	**Attribute / Element Type**	**Description**	**Occurrence**
AvlRef	qualifiedNameType	A reference to the single Approved Vendor List for all the suppliers identified and the total number in the IPC-2581 file. This feature is a method of checking completeness in file transfer.	0-1

4.7 Content: DictionaryStandard

The DictionaryStandard is intended to provide lookup information on predefined Standard Primitives. The DictionaryStandard is maintained as part of a substitution group schema. The intent is to have graphic descriptions available that are identified by their characteristics and a specific name (id). They may be reused throughout the file as appropriate. The name (id) of a StandardPrimitive must be unique within the DictionaryStandard.

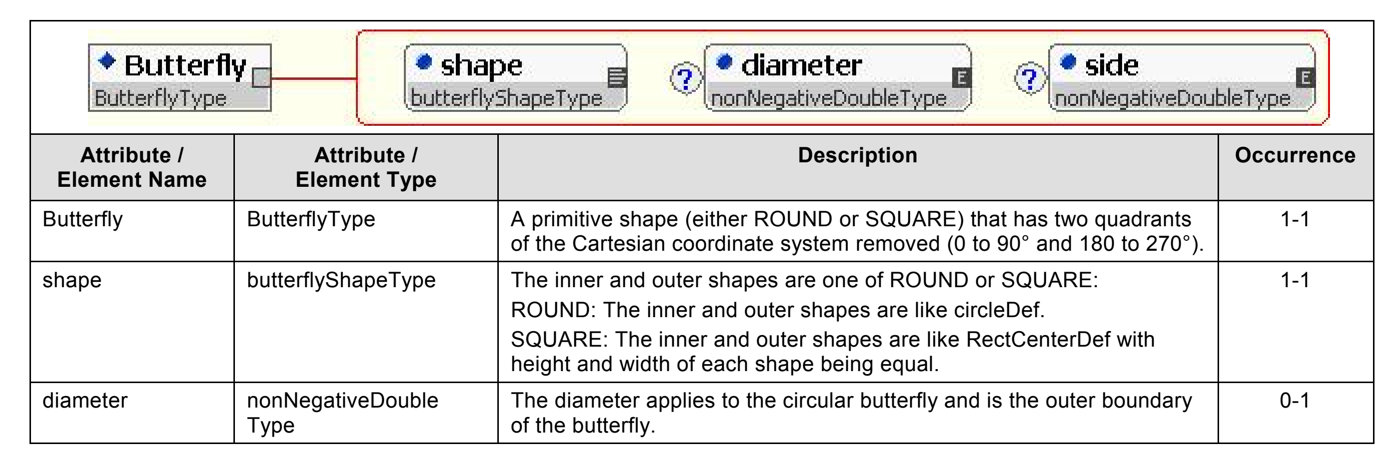


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryStandard	DictionaryStandard Type	An element that contains substitution group information using predefined descriptions of standard primitives identified by the 2581 standard and described by the user for reuse in the file.	0-1
units	unitsType	An enumerated string that may be one of the following: MILLIMETER | MICRON | INCH.	1-1
EntryStandard	EntryStandardType	An element that establishes the individual characteristic associated with a StandardPrimitive substitution shape that has been identified by the user of the IPC-2581 file.	0-n
Id	qualifiedNameType	The unique qualified name description assigned as an id for any `StandardPrimitive` for XML schema substitution.	1-1
StandardPrimitive	ABSTRACT	Any standard primitive that is part of the substitution group that permits the substitution of the `StandardShape` element.	1-n

The organization of the `DictionaryStandard` is accomplished in accordance with the substitution group description criteria. The `StandardPrimitive` description may be any of sixteen standard shapes according to the specific characteristics identified in the following paragraphs. The `StandardPrimitiveRef` function is used in the body of the 2581 file when a specific `StandardPrimitive` has been predefined, assigned a name, and the unique "id" is referenced in the file. This feature permits the use of either a predefined `StandardPrimitive`, or defining the details of a `StandardPrimitive` within the file. The description in the file must contain all the features of a particular primitive shape under the rules of the particular shape definition.

4.7.1 StandardPrimitive: Butterfly

A `Butterfly` is a `StandardPrimitive` shape that may have the external periphery be either round or square with two quadrants of the Cartesian coordinate system removed (0 to 90° and 180 to 270°). The round shape is defined by its diameter; the square shape is defined by an equal side dimension. The `Butterfly` is positioned by its point of origin, which is at the center of the `Butterfly`.



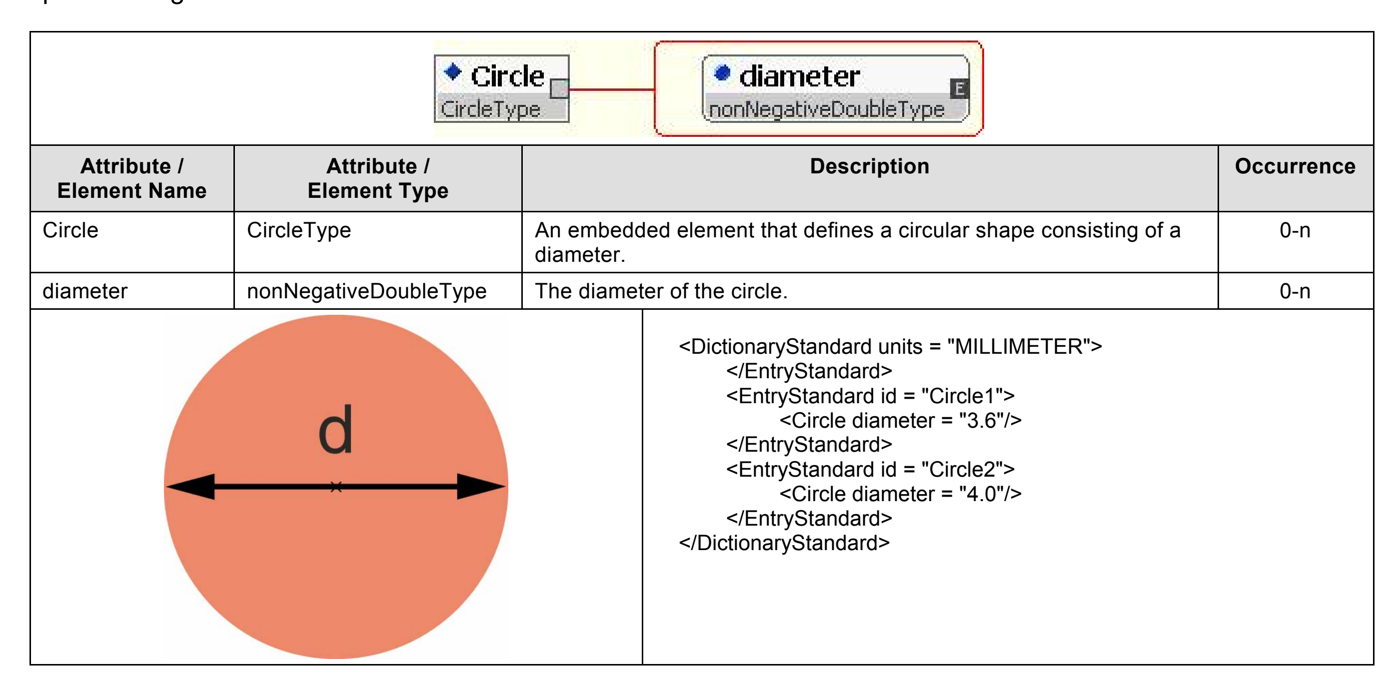
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Butterfly	ButterflyType	A primitive shape (either ROUND or SQUARE) that has two quadrants of the Cartesian coordinate system removed (0 to 90° and 180 to 270°).	1-1
shape	butterflyShapeType	The inner and outer shapes are one of ROUND or SQUARE: ROUND: The inner and outer shapes are like circleDef. SQUARE: The inner and outer shapes are like RectCenterDef with height and width of each shape being equal.	1-1
diameter	nonNegativeDouble Type	The diameter applies to the circular butterfly and is the outer boundary of the butterfly.	0-1

side	nonNegativeDouble Type	The width along the x-axis and the height along the y-axis of a square.	0-1

```
<DictionaryStandard units = "MILLIMETER">
      </EntryStandard>
      <EntryStandard id = "Butterfly1">
         <Butterfly shape = "ROUND" diameter = "3.2"/>
      </EntryStandard>
      <EntryStandard id = "Butterfly2">
         <Butterfly shape = "SQUARE" side = "1.8"/>
      </EntryStandard>
</DictionaryStandard>
```

4.7.2 StandardPrimitive: Circle

A `Circle` is a `StandardPrimitive` shape that defines a circle by the diameter of the circle. The point of origin is the center of a circle.



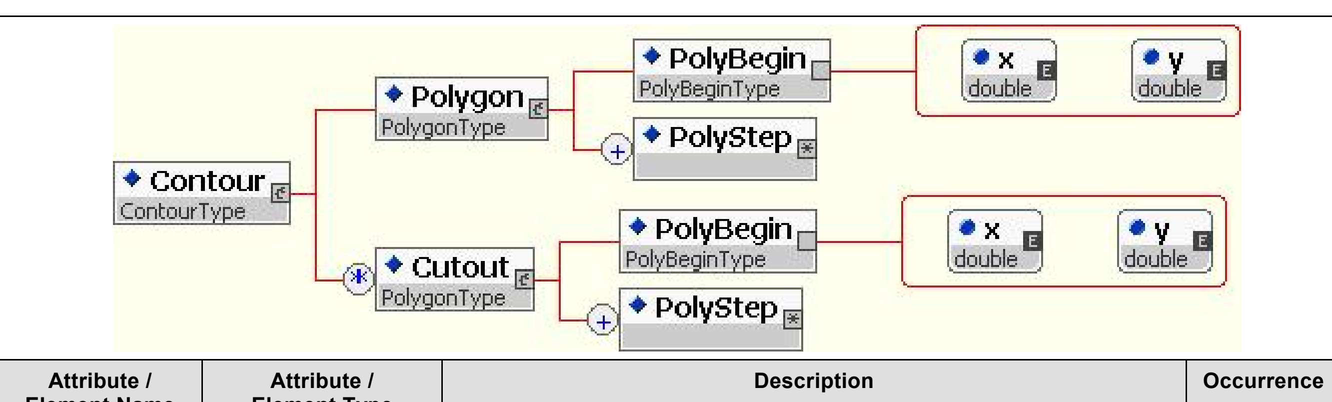
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Circle	CircleType	An embedded element that defines a circular shape consisting of a diameter.	0-n
diameter	nonNegativeDoubleType	The diameter of the circle.	0-n

```
<DictionaryStandard units = "MILLIMETER">
      </EntryStandard>
      <EntryStandard id = "Circle1">
            <Circle diameter = "3.6"/>
      </EntryStandard>
      <EntryStandard id = "Circle2">
            <Circle diameter = "4.0"/>
      </EntryStandard>
</DictionaryStandard>
```

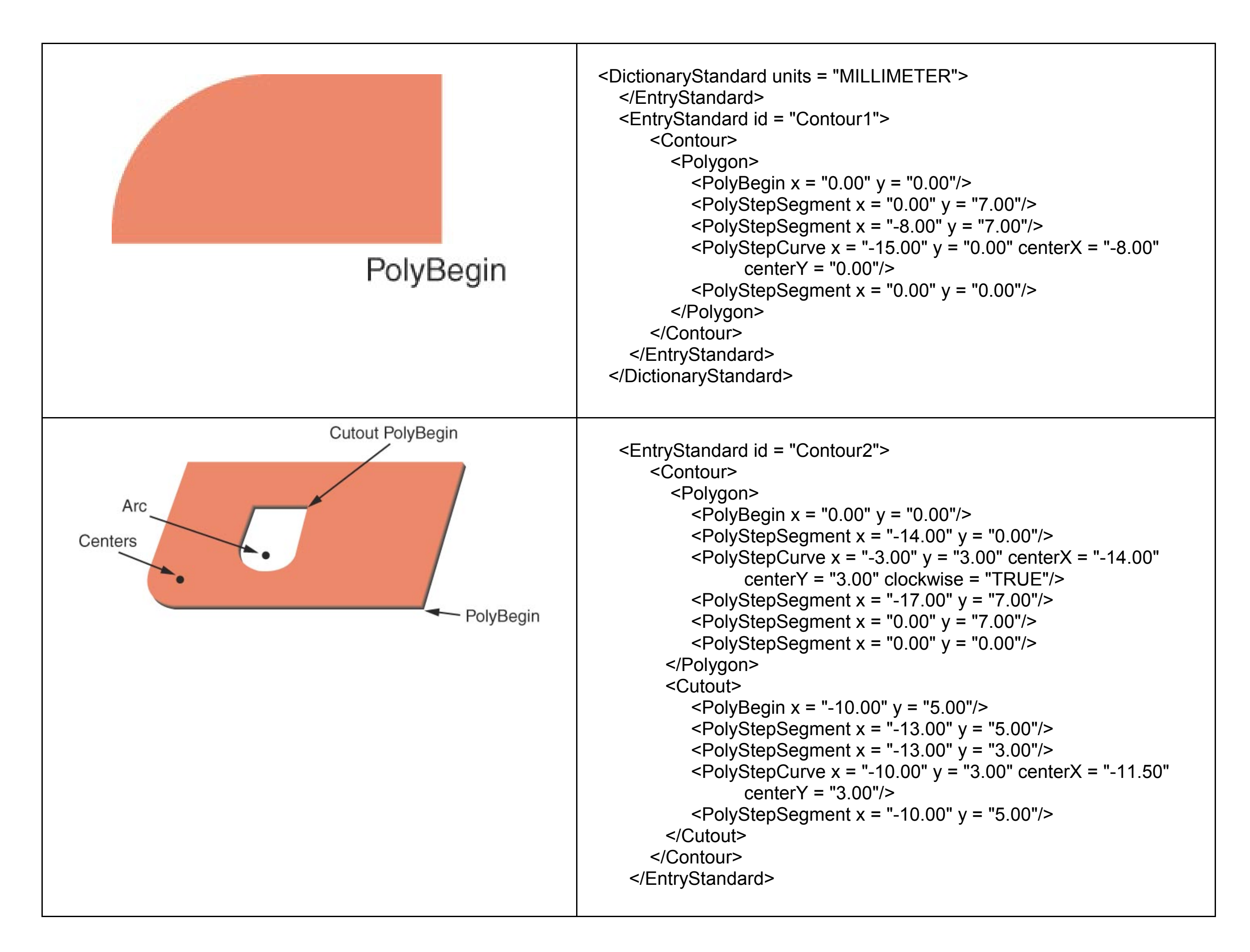
4.7.3 StandardPrimitive: Contour

The `Contour` element is a `StandardPrimitive` shape that defines a sequence of connected edges that form a polygon. An edge can be straight or circular. The `polygon` is a closed shape whose edges

do not cross. This same characteristic is also true for cutout, which represents the absence of material inside the polygon shape. The coordinates of the polygon, cutout, and subsequent cutouts are defined relative to the local coordinate system of the original polygon. The point of origin may be a centroid of the polygon or one of the corners that sets the 0/0 coordinate. This is the point used to place the polygon or to rotate the image. The cutout uses the same coordinates.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Contour	ContourType	A sequence of connected edges that form a polygon. An edge can be straight or circular.	1-1
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon.	1-1
PolyBegin	PolyBeginType	The PolyBegin element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The PolyStep element is a substitution group that defines a circular (PolyStepCurve) or straight line (PolyStepSegment) continuation of the polygon. The polystep direction may be clockwise or counterclockwise which must be consistent when any Arc description is used as one of the PolyStep elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1-n
Cutout	CutoutType	A polygon closed shape whose edges do not cross, which adopts the coordinates of the original polygon, however represents the absence of material within the original polygon shape.	0-n
PolyBegin	PolyBeginType	The PolyBegin element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The PolyStep element is a substitution group that defines a circular (PolyStepCurve) or straight line (PolyStepSegment) continuation of the polygon. The polystep direction may be clockwise or counterclockwise which must be consistent when any Arc description is used as one of the PolyStep elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1-n




```
<DictionaryStandard units = "MILLIMETER">
  </EntryStandard>
  <EntryStandard id = "Contour1">
      <Contour>
        <Polygon>
          <PolyBegin x = "0.00" y = "0.00"/>
          <PolyStepSegment x = "0.00" y = "7.00"/>
          <PolyStepSegment x = "-8.00" y = "7.00"/>
          <PolyStepCurve x = "-15.00" y = "0.00" centerX = "-8.00"
               centerY = "0.00"/>
          <PolyStepSegment x = "0.00" y = "0.00"/>
        </Polygon>
      </Contour>
    </EntryStandard>
  </DictionaryStandard>
```

```
  <EntryStandard id = "Contour2">
      <Contour>
        <Polygon>
          <PolyBegin x = "0.00" y = "0.00"/>
          <PolyStepSegment x = "-14.00" y = "0.00"/>
          <PolyStepCurve x = "-3.00" y = "3.00" centerX = "-14.00"
               centerY = "3.00" clockwise = "TRUE"/>
          <PolyStepSegment x = "-17.00" y = "7.00"/>
          <PolyStepSegment x = "0.00" y = "7.00"/>
          <PolyStepSegment x = "0.00" y = "0.00"/>
        </Polygon>
        <Cutout>
          <PolyBegin x = "-10.00" y = "5.00"/>
          <PolyStepSegment x = "-13.00" y = "5.00"/>
          <PolyStepSegment x = "-13.00" y = "3.00"/>
          <PolyStepCurve x = "-10.00" y = "3.00" centerX = "-11.50"
               centerY = "3.00"/>
          <PolyStepSegment x = "-10.00" y = "5.00"/>
        </Cutout>
      </Contour>
    </EntryStandard>
```

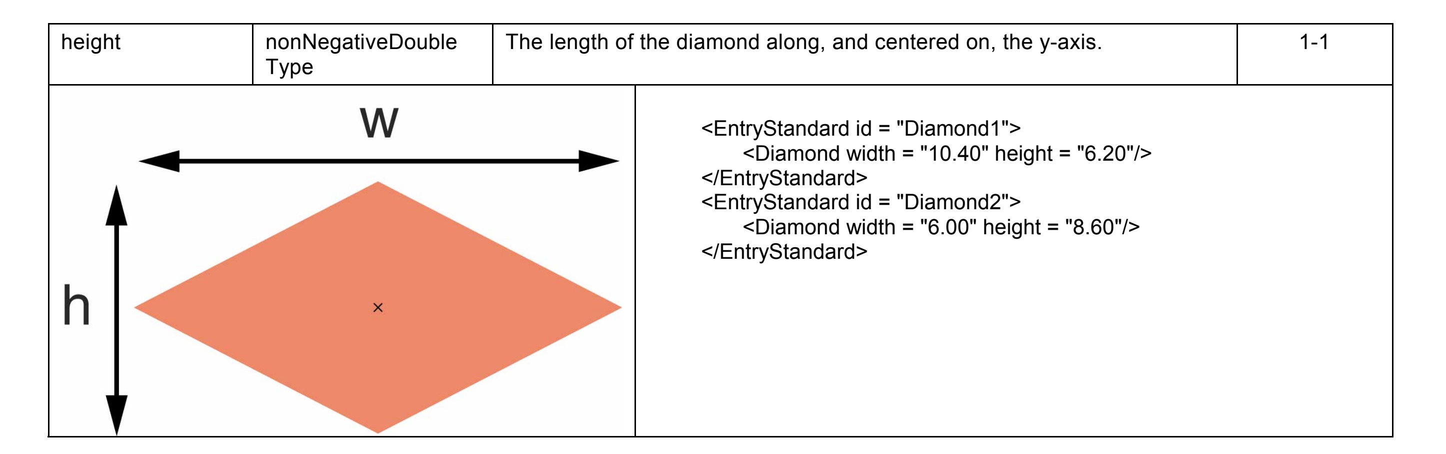
4.7.4 StandardPrimitive: Diamond

A `Diamond` is a 4-sided `StandardPrimitive` shape. The lengths of the sides of a diamond are always equal. A height and a width dimension specify the diamond. The first line defining the outline of the diamond is drawn between the point that is ½ the height dimension along the positive y-axis and the point that is ½ the width dimension along the x-axis. The same process is used to draw the other three lines of the diamond in each of the remaining quadrants. The `Diamond` is positioned with one of its corners facing the North direction.

Diamond DiamondType — width nonNegativeDoubleType — height nonNegativeDoubleType

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Diamond	DiamondType	A primitive shape with four equal sides that are extended from its horizontal center to its vertical center. The lines converge into a point both horizontally and vertically. The overall description of the shape is controlled by the width (distance between vertical point) and the height (distance between horizontal point).	1-1
width	nonNegativeDouble Type	The length of the diamond along, and centered on, the x-axis.	1-1

height	nonNegativeDouble Type	The length of the diamond along, and centered on, the y-axis.	1-1




```
<EntryStandard id = "Diamond1">
    <Diamond width = "10.40" height = "6.20"/>
</EntryStandard>
<EntryStandard id = "Diamond2">
    <Diamond width = "6.00" height = "8.60"/>
</EntryStandard>
```

4.7.5 StandardPrimitive: Donut

A `Donut` is a `StandardPrimitive` shape composed of two concentric identical shapes. The shapes are the same but of different sizes with the outer diameter (OD) being larger than the inner diameter (ID). The shapes must be identical and may be square, round, hexagonal, or octagonal. The center of a `Donut` is also the point of origin of the primitive. The hexagonal and octagonal shapes are defined with a point of the shape facing the North direction.

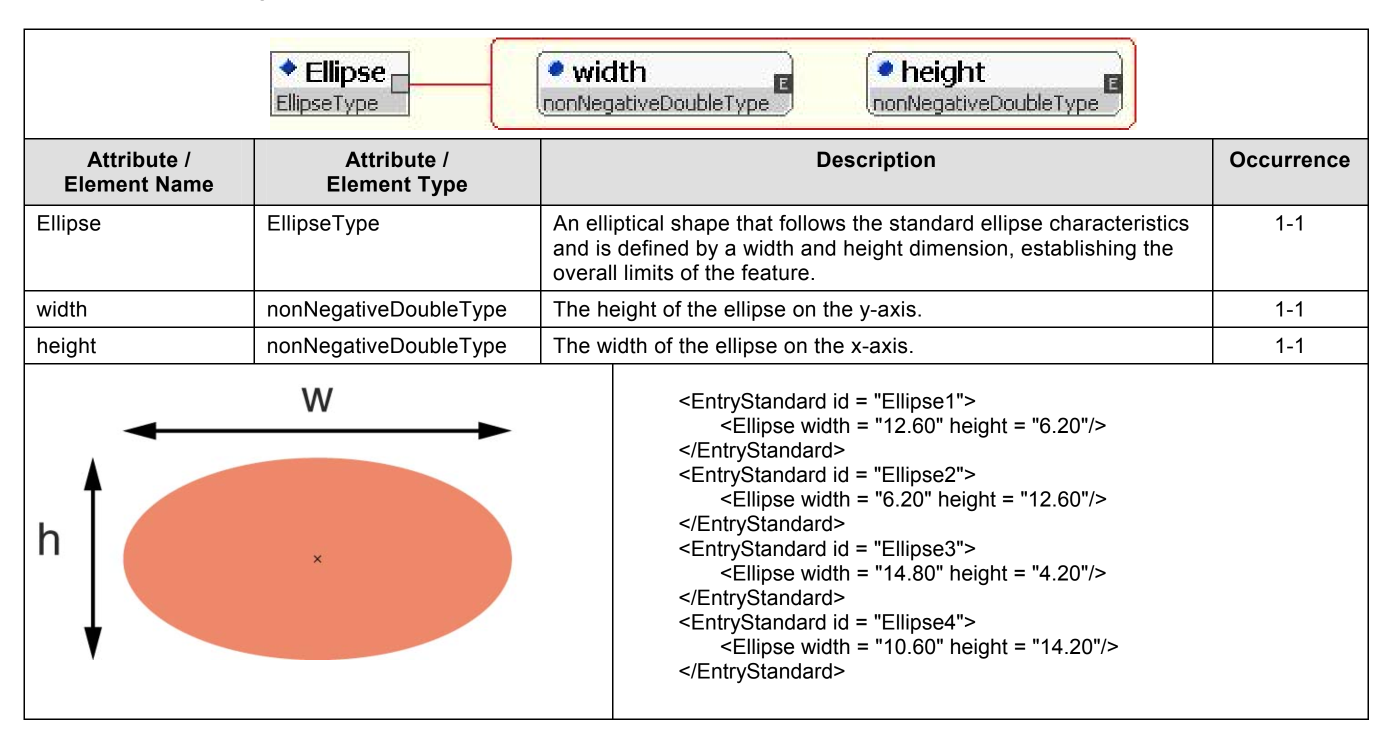
Donut (DonutType) — shape (donutShapeType) — outerDiameter (nonNegativeDoubleType) — innerDiameter (nonNegativeDoubleType)

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Donut	DonutType	A round, square, hexagon, or octagon shape consisting of an outer diamer and inner diameter that define physical characteristics of the donut.	1-1
shape	donutShapeType	The inner and outer shapes are one of ROUND, SQUARE , HEXAGON or OCTAGON: ROUND – The inner and outer shapes are like a circle. SQUARE – The inner and outer shapes are like a RectCenter with height and width of each shape being equal. HEXAGON – The inner and outer shapes are like a Hexagon. OCTAGON – The inner and outer shapes are like an Octagon.	1-1
outerDiameter	nonNegativeDouble Type	The outer boundary of the filled region. The meaning based on donutShape: ROUND –The diameter of the circle is the outer boundary of the donut. The center of the circle is at the origin of the donut. SQUARE –The width along the x-axis and the height along the y-axis of a square at the inner boundary of the donut. The center of the square is at the origin. HEXAGON – The point-to-point measurement on the x-axis of the hexagon that forms the outer boundary of the donut. OCTAGON – The point-to-point measurement on the x-axis of the octagon that forms the outer boundary of the donut.	1-1

innerDiameter	nonNegativeDouble Type	The inner boundary of the filled region. The meaning based on donutShape : ROUND – The diameter of the circle is the inner boundary of the donut. The center of the circle is at the origin of the donut. SQUARE – The width along the x-axis and height along the y-axis of a square at the inner boundary of the donut. The center of the square is at the origin. HEXAGON – The point-to-point measurement on the x-axis of the hexagon that forms the inner boundary of the donut. OCTAGON – the point-to-point measurement on the x-axis of the octagon that forms the inner boundary of the donut.	1-1
od id	<EntryStandard id = "Donut1"> <Donut shape = "ROUND" outerDiameter = "6.8" innerDiameter = "4.8"/> </EntryStandard> <EntryStandard id = "Donut2"> <Donut shape = "ROUND" outerDiameter = "8.6" innerDiameter = "7.4"/> </EntryStandard>		
od id	<EntryStandard id = "Donut3"> <Donut shape = "SQUARE" outerDiameter = "6.8" innerDiameter = "5.0"/> </EntryStandard> <EntryStandard id = "Donut4"> <Donut shape = "SQUARE" outerDiameter = "8.20" innerDiameter = "6.20"/> </EntryStandard>		
od id	<EntryStandard id = "Donut5"> <Donut shape = "HEXAGON" outerDiameter = "12.40" innerDiameter = "10.20"/> </EntryStandard> <EntryStandard id = "Donut6"> <Donut shape = "HEXAGON" outerDiameter = "10.00" innerDiameter = "8.00"/> </EntryStandard>		
od id	<EntryStandard id = "Donut7"> <Donut shape = "OCTAGON" outerDiameter = "11.60" innerDiameter = "10.00"/> </EntryStandard> <EntryStandard id = "Donut8"> <Donut shape = "OCTAGON" outerDiameter = "12.00" innerDiameter = "10.00"/> </EntryStandard>		

4.7.6 StandardPrimitive: Ellipse

The `Ellipse` is a `StandardPrimitive` shape that is an ellipse with the standard ellipse characteristics. The shape is defined by the width and height dimension. The `Ellipse` is positioned with its point of origin at the center of the `width` and `height` dimensions.

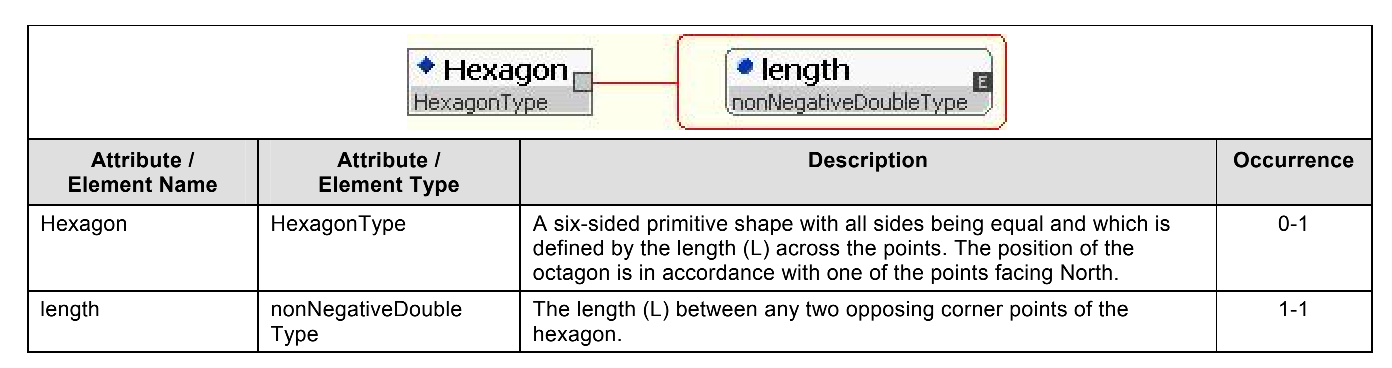


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Ellipse	EllipseType	An elliptical shape that follows the standard ellipse characteristics and is defined by a width and height dimension, establishing the overall limits of the feature.	1-1
width	nonNegativeDoubleType	The height of the ellipse on the y-axis.	1-1
height	nonNegativeDoubleType	The width of the ellipse on the x-axis.	1-1

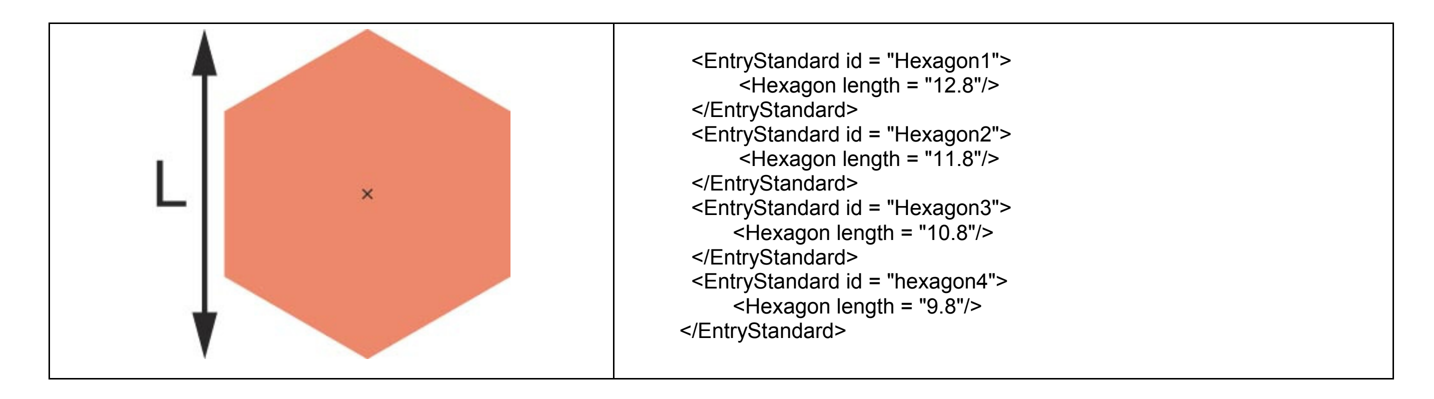
```
<EntryStandard id = "Ellipse1">
    <Ellipse width = "12.60" height = "6.20"/>
</EntryStandard>
<EntryStandard id = "Ellipse2">
    <Ellipse width = "6.20" height = "12.60"/>
</EntryStandard>
<EntryStandard id = "Ellipse3">
    <Ellipse width = "14.80" height = "4.20"/>
</EntryStandard>
<EntryStandard id = "Ellipse4">
    <Ellipse width = "10.60" height = "14.20"/>
</EntryStandard>
```

4.7.7 StandardPrimitive: Hexagon

A `Hexagon` is a six-sided `StandardPrimitive` shape with each of the sides being equal in length and with all angles between adjacent sides also being equal. The orientation of the hexagon is in accordance with one of its points facing the North direction. Only one dimension is required and that is the length across the points. `Rotation` is accomplished using `Xform` at the time the hexagon is instantiated.



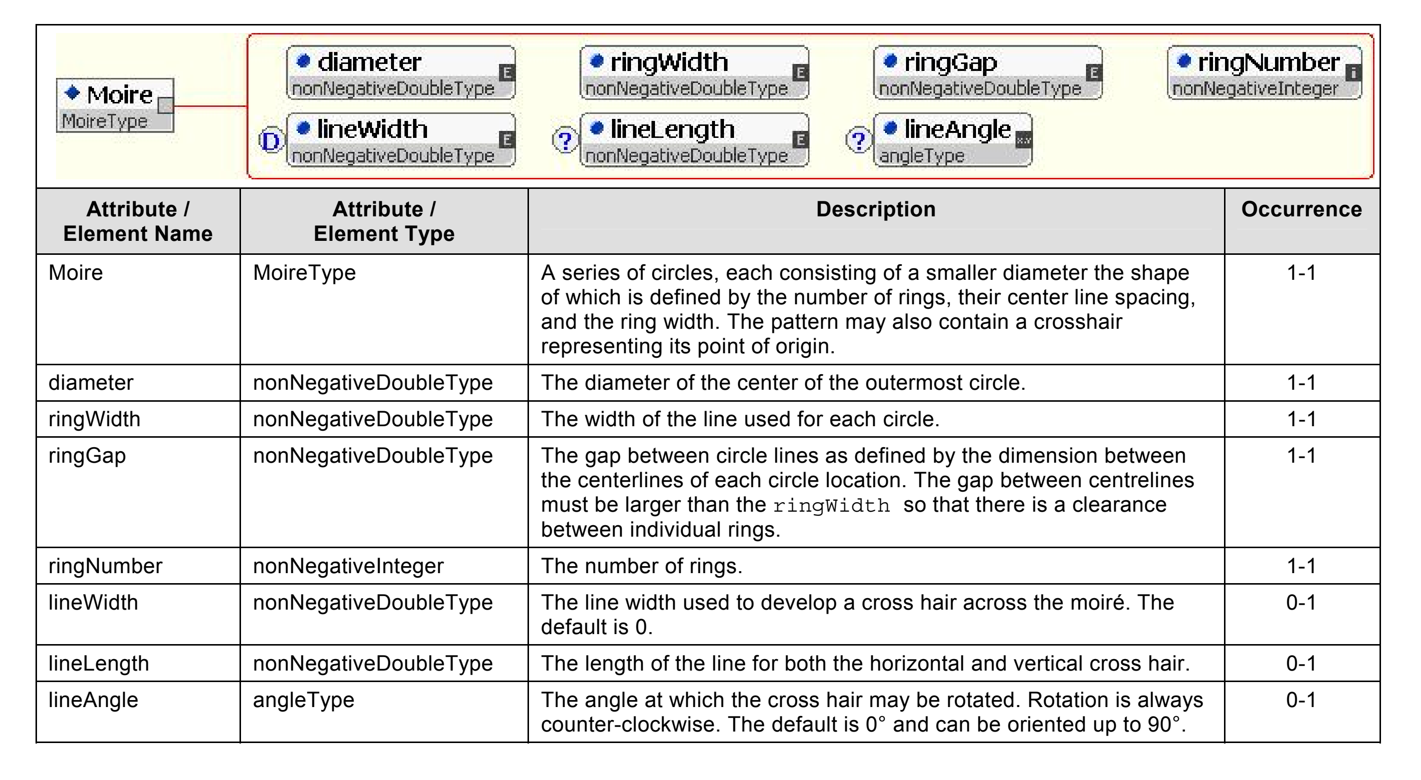
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Hexagon	HexagonType	A six-sided primitive shape with all sides being equal and which is defined by the length (L) across the points. The position of the octagon is in accordance with one of the points facing North.	0-1
length	nonNegativeDouble Type	The length (L) between any two opposing corner points of the hexagon.	1-1



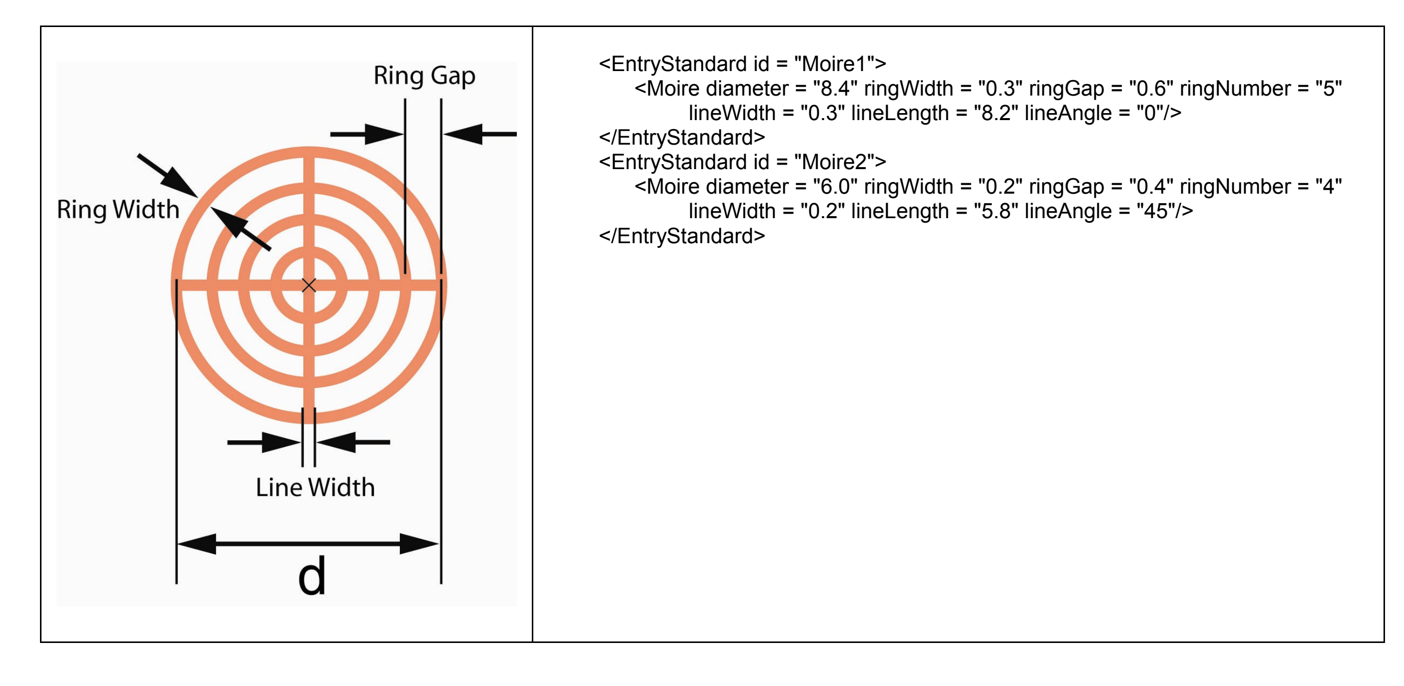

```
<EntryStandard id = "Hexagon1">
      <Hexagon length = "12.8"/>
</EntryStandard>
<EntryStandard id = "Hexagon2">
      <Hexagon length = "11.8"/>
</EntryStandard>
<EntryStandard id = "Hexagon3">
      <Hexagon length = "10.8"/>
</EntryStandard>
<EntryStandard id = "hexagon4">
      <Hexagon length = "9.8"/>
</EntryStandard>
```

4.7.8 StandardPrimitive: Moire

The `Moire` is a primitive shape that consists of a series of circles each with a smaller diameter. The `Moire` is used as an assist in image registration. The `Moire` may be only circles or may also contain a crosshair line to assist in human acknowledgement of moiré alignment. The shape is defined by the number of rings, their center line spacing and the ring line width. The line spacing must be larger than the line width. The crosshair lines can also be described. The `Moire` pattern is positioned using its point of origin which is the center of the ring pattern.



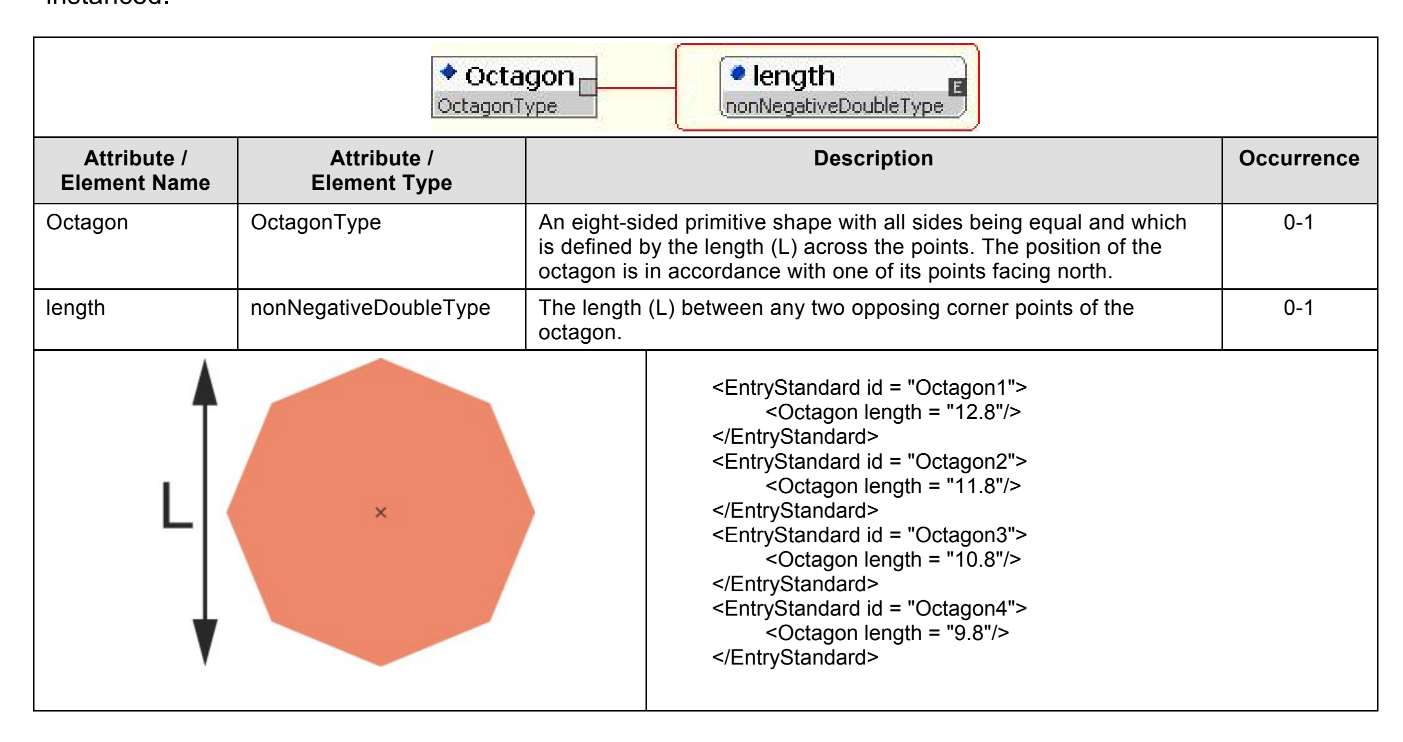
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Moire	MoireType	A series of circles, each consisting of a smaller diameter the shape of which is defined by the number of rings, their center line spacing, and the ring width. The pattern may also contain a crosshair representing its point of origin.	1-1
diameter	nonNegativeDoubleType	The diameter of the center of the outermost circle.	1-1
ringWidth	nonNegativeDoubleType	The width of the line used for each circle.	1-1
ringGap	nonNegativeDoubleType	The gap between circle lines as defined by the dimension between the centerlines of each circle location. The gap between centrelines must be larger than the `ringWidth` so that there is a clearance between individual rings.	1-1
ringNumber	nonNegativeInteger	The number of rings.	1-1
lineWidth	nonNegativeDoubleType	The line width used to develop a cross hair across the moiré. The default is 0.	0-1
lineLength	nonNegativeDoubleType	The length of the line for both the horizontal and vertical cross hair.	0-1
lineAngle	angleType	The angle at which the cross hair may be rotated. Rotation is always counter-clockwise. The default is 0° and can be oriented up to 90°.	0-1




```
<EntryStandard id = "Moire1">
    <Moire diameter = "8.4" ringWidth = "0.3" ringGap = "0.6" ringNumber = "5"
        lineWidth = "0.3" lineLength = "8.2" lineAngle = "0"/>
</EntryStandard>
<EntryStandard id = "Moire2">
    <Moire diameter = "6.0" ringWidth = "0.2" ringGap = "0.4" ringNumber = "4"
        lineWidth = "0.2" lineLength = "5.8" lineAngle = "45"/>
</EntryStandard>
```

4.7.9 StandardPrimitive: Octagon

An `Octagon` is an eight-sided `StandardPrimitive` shape with each of the sides being equal in length and with all angles between adjacent sides also being equal. The orientation of the `Octagon` is in accordance with one of its points facing the North direction. Only one dimension is required and that is the length across the points. `Rotation` is accomplished using `Xform` at the time the `Octagon` is instanced.

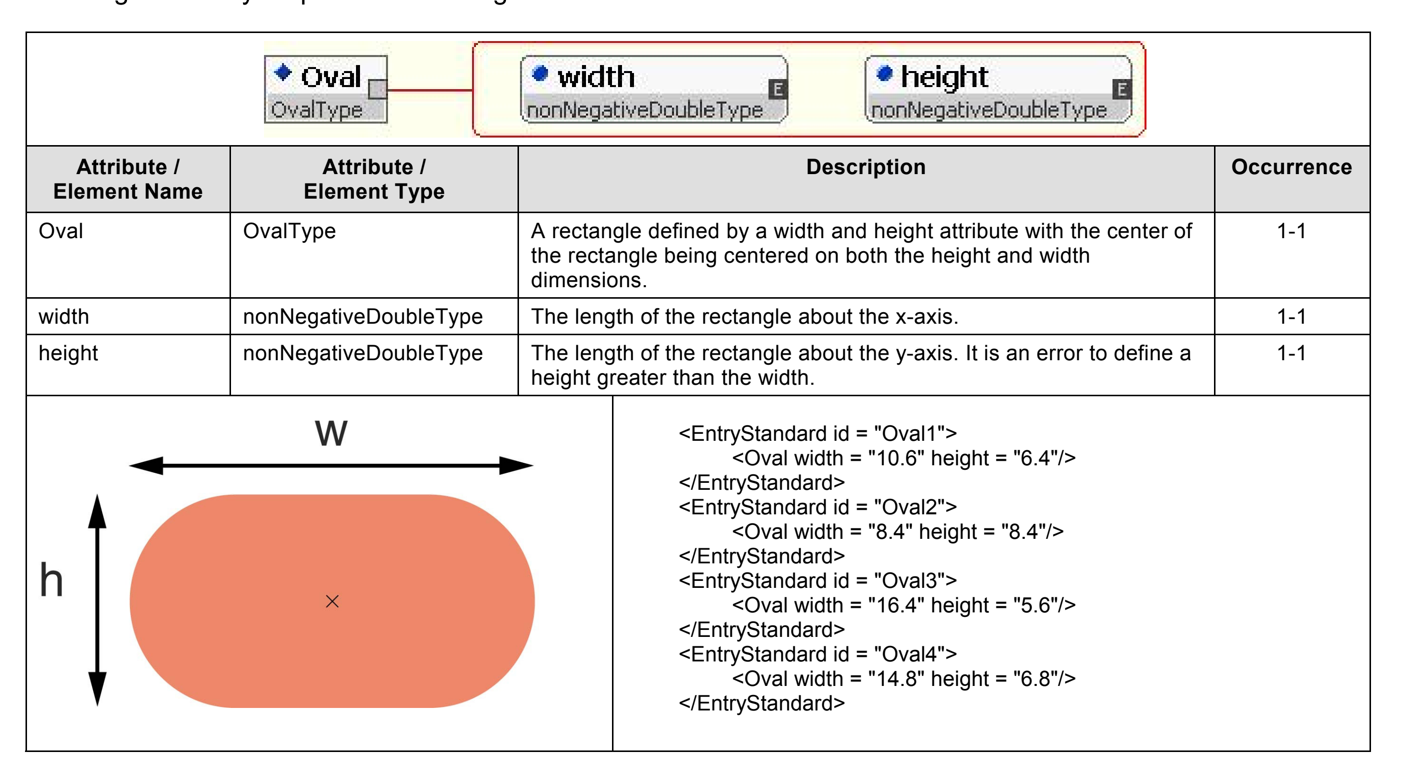


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Octagon	OctagonType	An eight-sided primitive shape with all sides being equal and which is defined by the length (L) across the points. The position of the octagon is in accordance with one of its points facing north.	0-1
length	nonNegativeDoubleType	The length (L) between any two opposing corner points of the octagon.	0-1

```
<EntryStandard id = "Octagon1">
    <Octagon length = "12.8"/>
</EntryStandard>
<EntryStandard id = "Octagon2">
    <Octagon length = "11.8"/>
</EntryStandard>
<EntryStandard id = "Octagon3">
    <Octagon length = "10.8"/>
</EntryStandard>
<EntryStandard id = "Octagon4">
    <Octagon length = "9.8"/>
</EntryStandard>
```

4.7.10 StandardPrimitive: Oval

An `Oval` is a `StandardPrimitive` shape that defines a rectangle with a complete radius (180 degree arc) at each end. The base rectangle is defined by a width attribute and a height attribute with the center of the rectangle being centered on both the height and width dimensions. The center of the `Oval` rectangle is the point of origin of the shape. The rectangle is defined with edges parallel to the x-axis and y-axis relative to the local coordinate system. Rotation is about the point of origin. The `Oval` is defined with the radius located along the y-axis sides. The radius on the ends of the oval shaped rectangle is always equal to ½ the height.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Oval	OvalType	A rectangle defined by a width and height attribute with the center of the rectangle being centered on both the height and width dimensions.	1-1
width	nonNegativeDoubleType	The length of the rectangle about the x-axis.	1-1
height	nonNegativeDoubleType	The length of the rectangle about the y-axis. It is an error to define a height greater than the width.	1-1

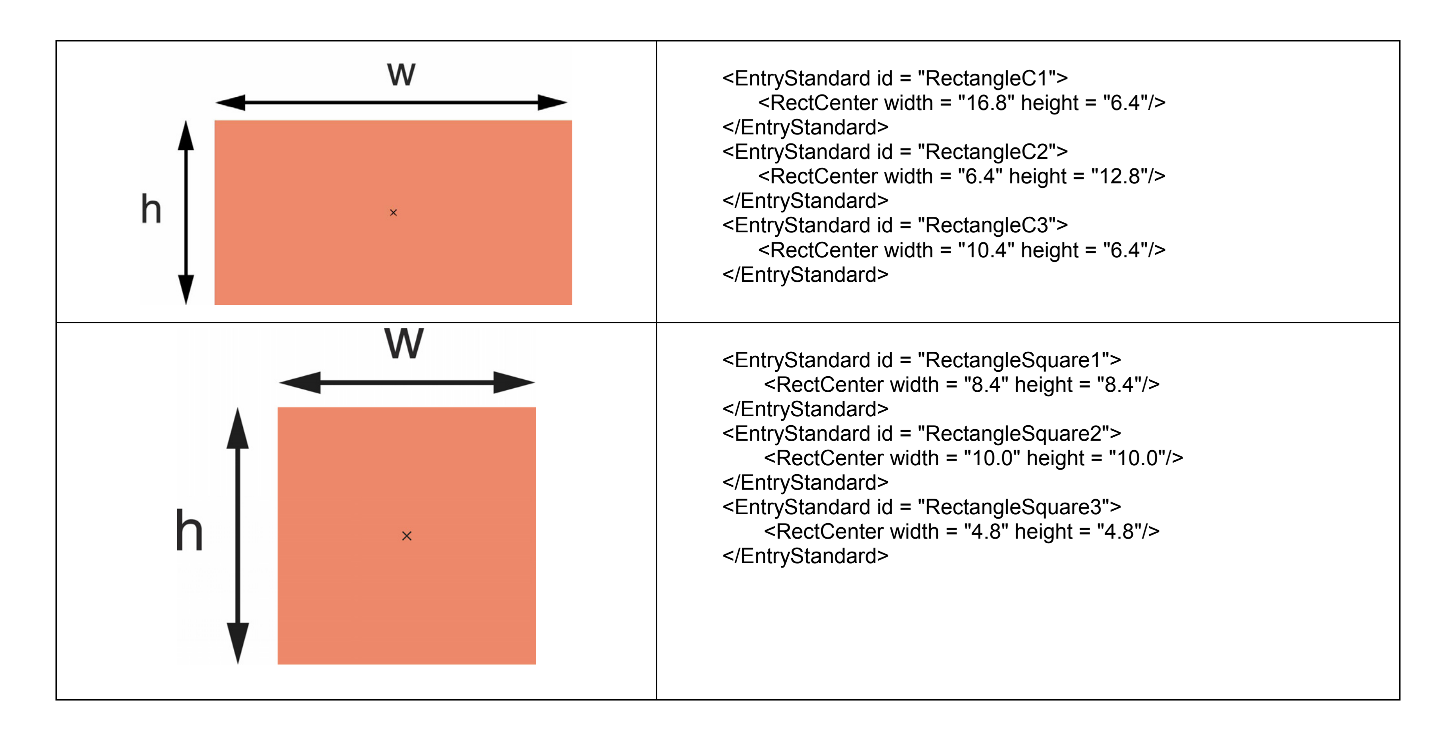
```
<EntryStandard id = "Oval1">
        <Oval width = "10.6" height = "6.4"/>
</EntryStandard>
<EntryStandard id = "Oval2">
        <Oval width = "8.4" height = "8.4"/>
</EntryStandard>
<EntryStandard id = "Oval3">
        <Oval width = "16.4" height = "5.6"/>
</EntryStandard>
<EntryStandard id = "Oval4">
        <Oval width = "14.8" height = "6.8"/>
</EntryStandard>
```

4.7.11 StandardPrimitive: RectCenter

A `RectCenter` is a primitive shape that defines a rectangle by a `width` attribute and a `height` attribute with the center of the rectangle being centered on both the height and width dimensions. The center of the `RectCenter` rectangle is the point of origin of the shape. The rectangle is defined with edges parallel to the x-axis and y-axis relative to the local coordinate system. Rotation is about the point of origin. The `RectCenter` is also used to represent a square shape. The characteristics of the square would be to have the width and height equal.

RectCenter
RectCenterType
width
nonNegativeDoubleType
height
nonNegativeDoubleType

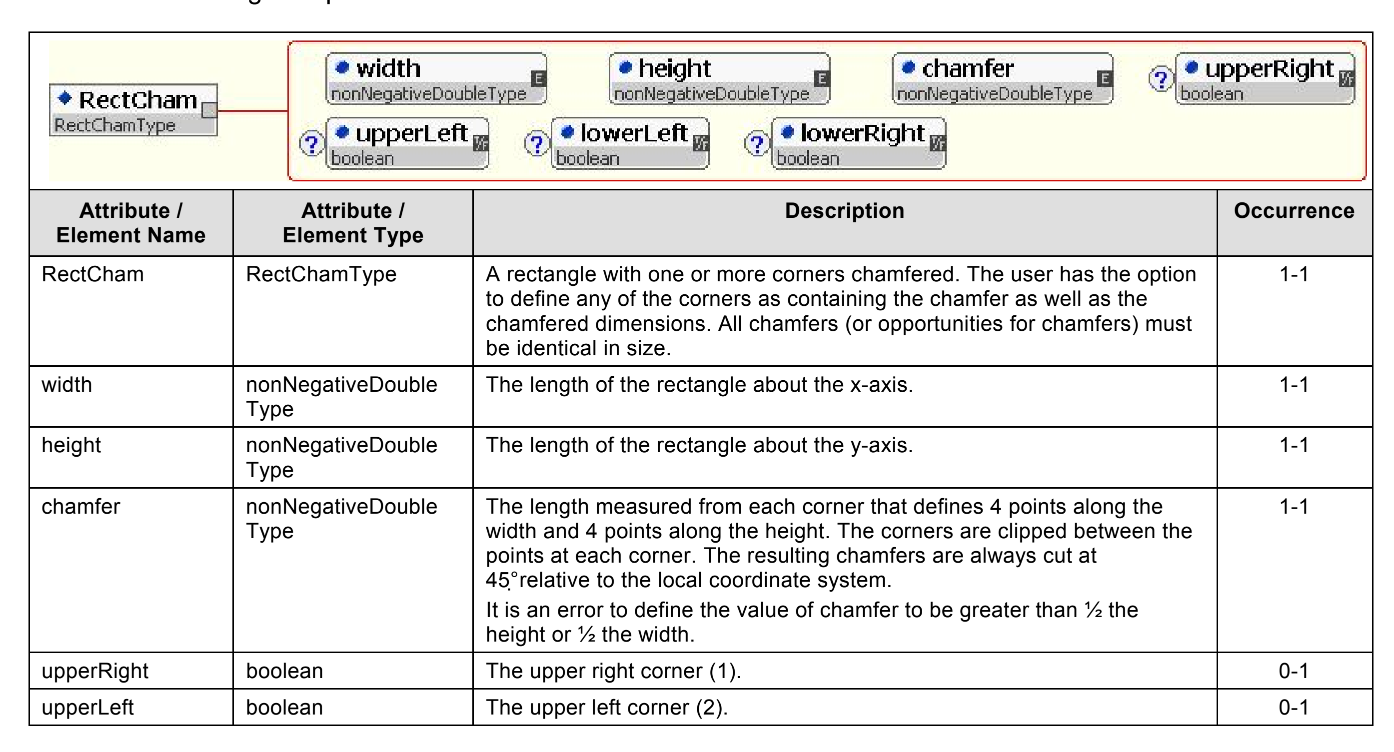
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
RectCenter	RectCenterType	The characteristics of a rectangle defined by a width and height dimension consistent with a horizontal position on the Cartesian coordinate system	1-1
width	nonNegativeDoubleType	The length of the rectangle about the x-axis.	1-1
height	nonNegativeDoubleType	The length of the rectangle about the y-axis.	1-1



(figure)	<EntryStandard id = "RectangleC1"> <RectCenter width = "16.8" height = "6.4"/> </EntryStandard> <EntryStandard id = "RectangleC2"> <RectCenter width = "6.4" height = "12.8"/> </EntryStandard> <EntryStandard id = "RectangleC3"> <RectCenter width = "10.4" height = "6.4"/> </EntryStandard>
(figure)	<EntryStandard id = "RectangleSquare1"> <RectCenter width = "8.4" height = "8.4"/> </EntryStandard> <EntryStandard id = "RectangleSquare2"> <RectCenter width = "10.0" height = "10.0"/> </EntryStandard> <EntryStandard id = "RectangleSquare3"> <RectCenter width = "4.8" height = "4.8"/> </EntryStandard>

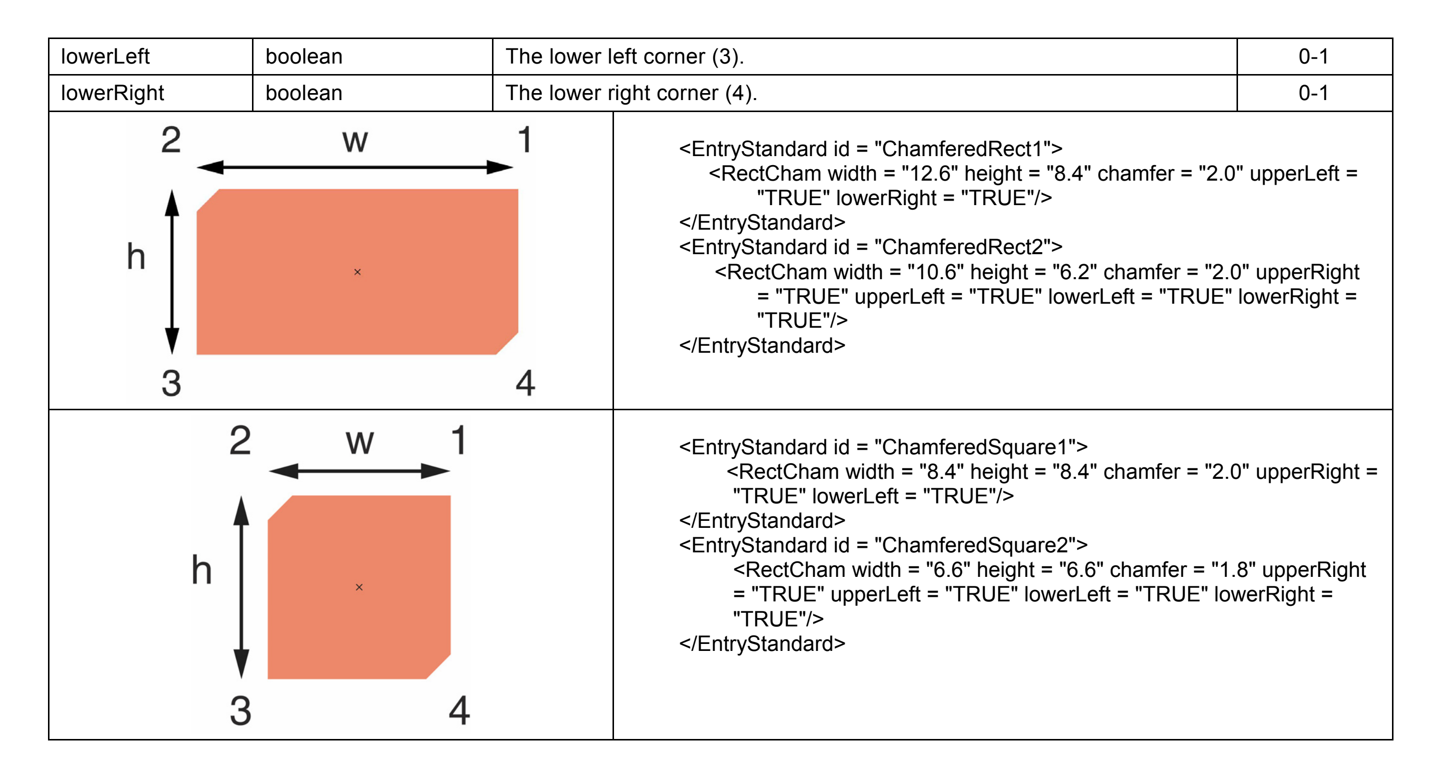
4.7.12 StandardPrimitive: RectCham

A `RectCham` is a `StandardPrimitive` shape that defines a rectangle with chamfered corners. The base rectangle is defined by a `width` attribute and a `height` attribute with the center of the rectangle being centered on both the height and width dimensions. The center of the `RectCham` rectangle is the point of origin of the shape. The rectangle is defined with edges parallel to the x-axis and y-axis relative to the local coordinate system. Rotation is about the point of origin. The `RectCham` is also used to represent a square shape with chamfered corners. The characteristics of the square would be to have the width and height equal.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
RectCham	RectChamType	A rectangle with one or more corners chamfered. The user has the option to define any of the corners as containing the chamfer as well as the chamfered dimensions. All chamfers (or opportunities for chamfers) must be identical in size.	1-1
width	nonNegativeDouble Type	The length of the rectangle about the x-axis.	1-1
height	nonNegativeDouble Type	The length of the rectangle about the y-axis.	1-1
chamfer	nonNegativeDouble Type	The length measured from each corner that defines 4 points along the width and 4 points along the height. The corners are clipped between the points at each corner. The resulting chamfers are always cut at 45°relative to the local coordinate system. It is an error to define the value of chamfer to be greater than ½ the height or ½ the width.	1-1
upperRight	boolean	The upper right corner (1).	0-1
upperLeft	boolean	The upper left corner (2).	0-1

lowerLeft	boolean	The lower left corner (3).	0-1
lowerRight	boolean	The lower right corner (4).	0-1

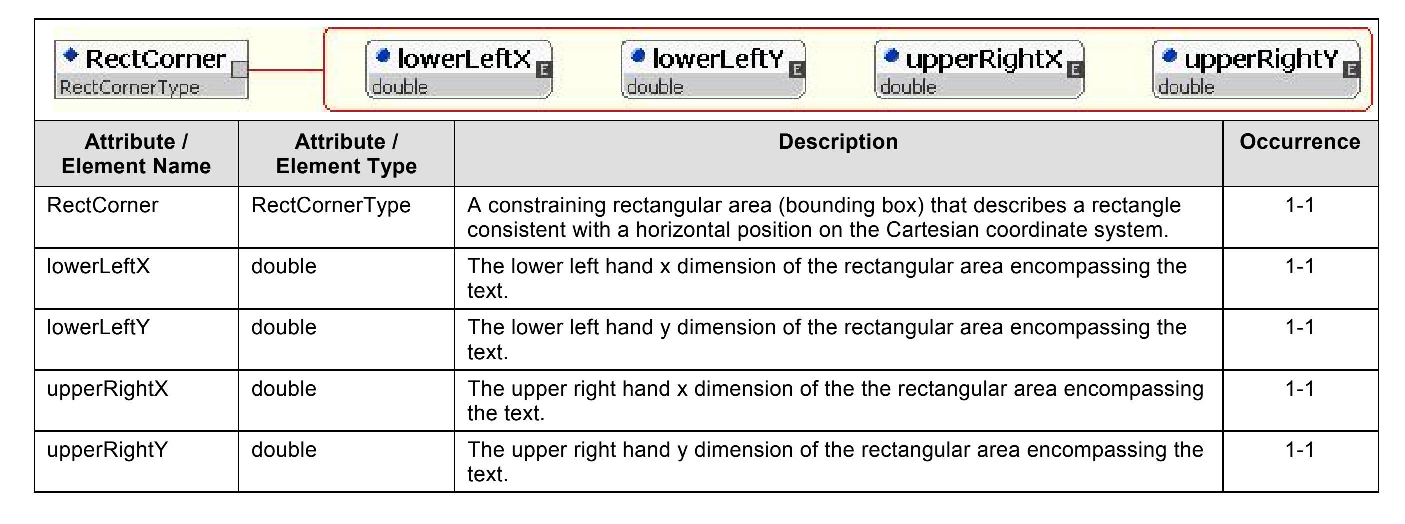



```
<EntryStandard id = "ChamferedRect1">
    <RectCham width = "12.6" height = "8.4" chamfer = "2.0" upperLeft =
         "TRUE" lowerRight = "TRUE"/>
</EntryStandard>
<EntryStandard id = "ChamferedRect2">
     <RectCham width = "10.6" height = "6.2" chamfer = "2.0" upperRight
         = "TRUE" upperLeft = "TRUE" lowerLeft = "TRUE" lowerRight =
         "TRUE"/>
</EntryStandard>
```

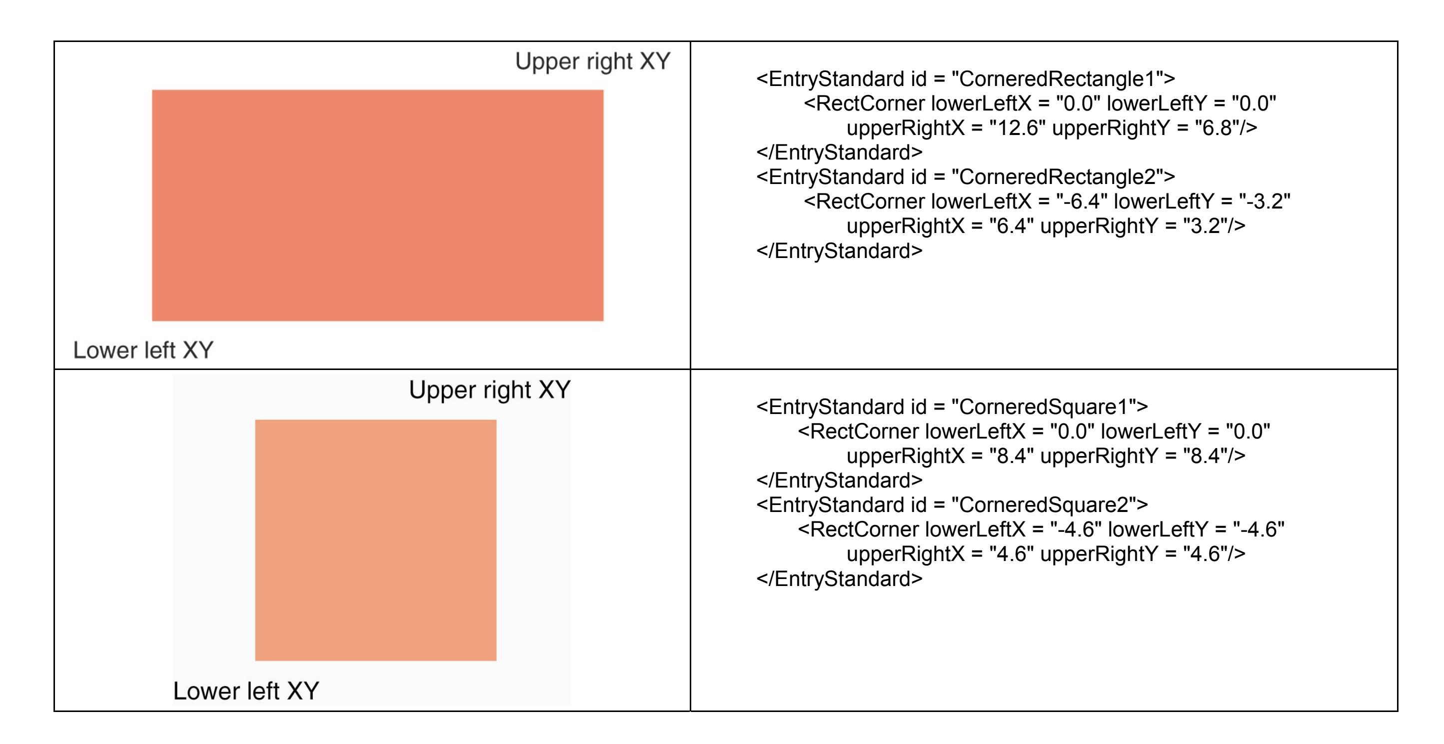
```
<EntryStandard id = "ChamferedSquare1">
      <RectCham width = "8.4" height = "8.4" chamfer = "2.0" upperRight =
       "TRUE" lowerLeft = "TRUE"/>
</EntryStandard>
<EntryStandard id = "ChamferedSquare2">
       <RectCham width = "6.6" height = "6.6" chamfer = "1.8" upperRight
       = "TRUE" upperLeft = "TRUE" lowerLeft = "TRUE" lowerRight =
       "TRUE"/>
</EntryStandard>
```

4.7.13 StandardPrimitive: RectCorner

A `RectCorner` is a `StandardPrimitive` shape that defines a rectangle. The element describes the lower left and upper right corners of the rectangle. The point of origin of a `RectCorner` rectangle is (0, 0). This can be coincident with attribute `lowerLeftX` and `lowerLeftY`, the lower left corner of the rectangle, but there is no requirement for that location to be at (0, 0). The rectangle is defined with edges parallel to the x-axis and y-axis relative to the local coordinate system. Rotation is about the point of origin, not about the lower left or upper right corners.

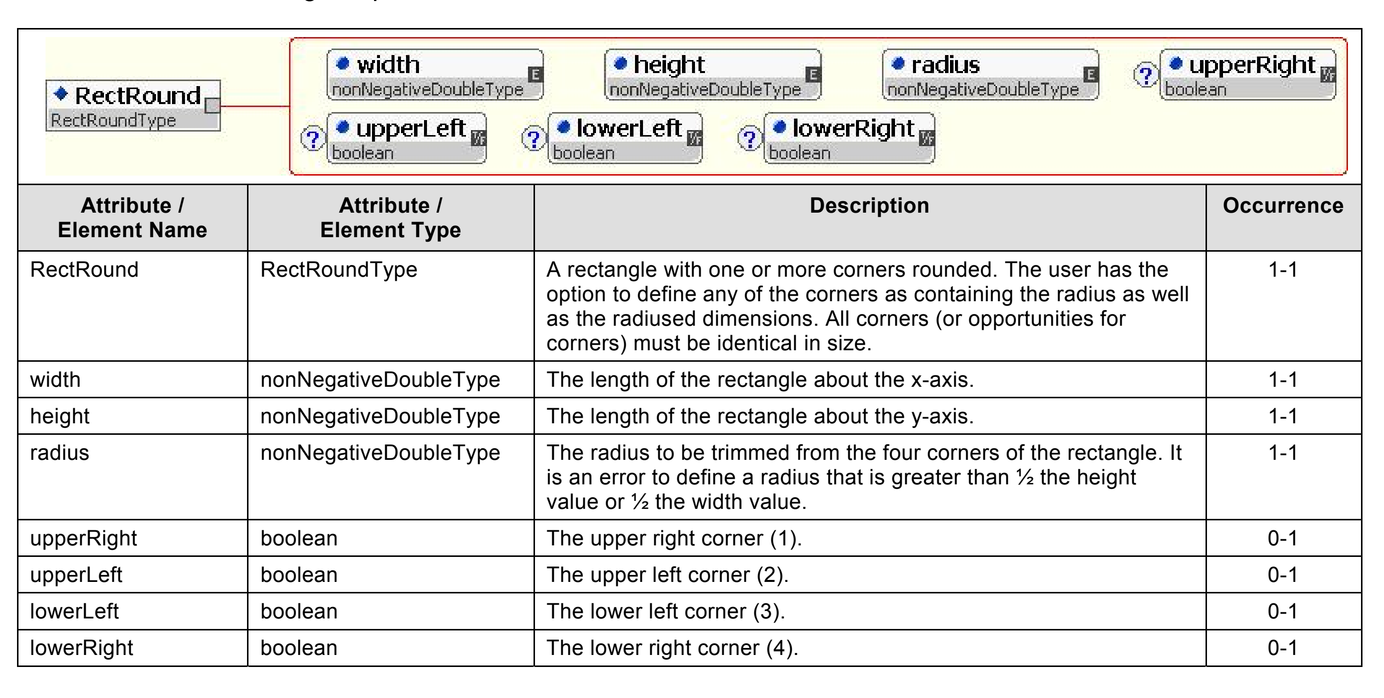


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
RectCorner	RectCornerType	A constraining rectangular area (bounding box) that describes a rectangle consistent with a horizontal position on the Cartesian coordinate system.	1-1
lowerLeftX	double	The lower left hand x dimension of the rectangular area encompassing the text.	1-1
lowerLeftY	double	The lower left hand y dimension of the rectangular area encompassing the text.	1-1
upperRightX	double	The upper right hand x dimension of the the rectangular area encompassing the text.	1-1
upperRightY	double	The upper right hand y dimension of the rectangular area encompassing the text.	1-1

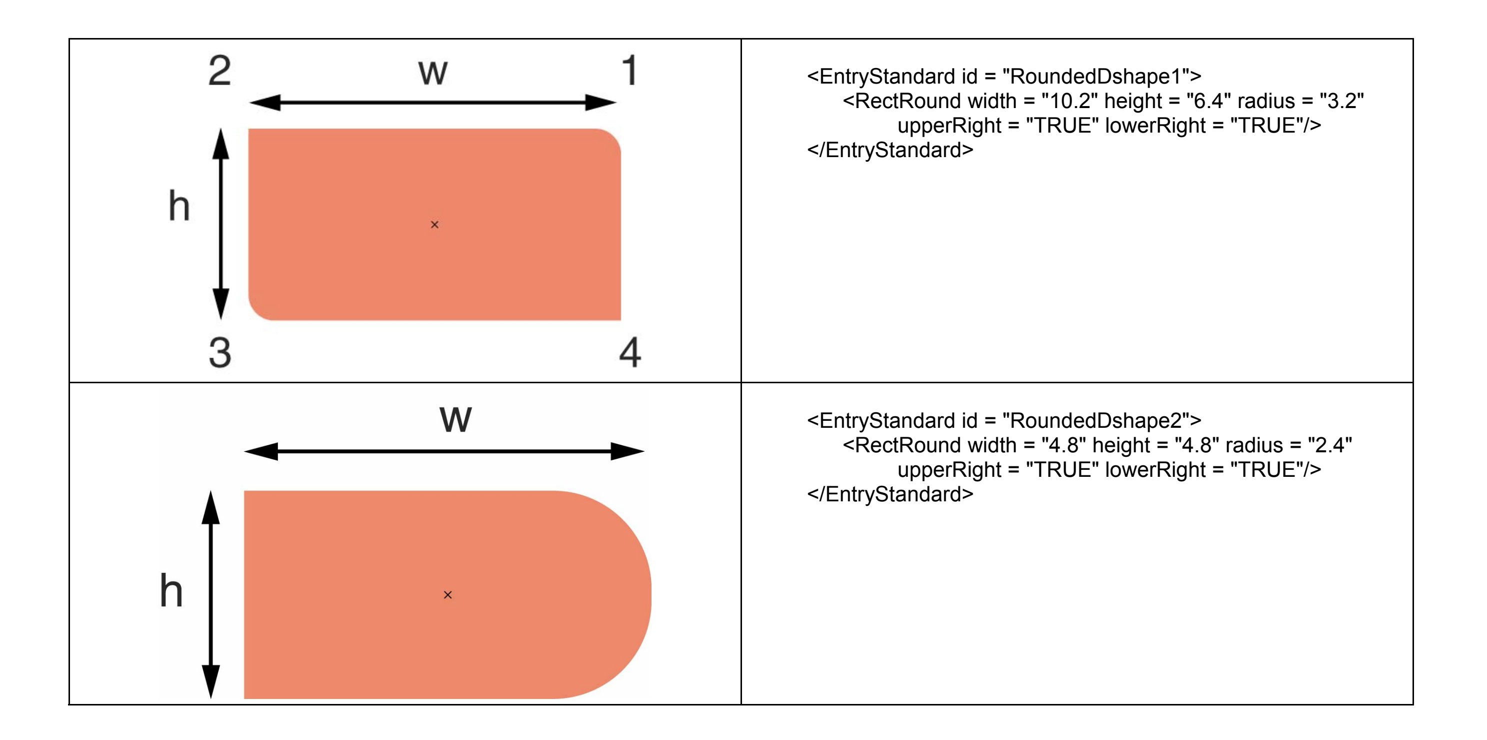


4.7.14 StandardPrimitive: RectRound

A `RectRound` is a `StandardPrimitive` shape that defines a rectangle with radius corners. The base rectangle is defined by a width attribute and a height attribute with the center of the rectangle being centered on both the height and width dimensions. The center of the `RectRound` rectangle is the point of origin of the shape. The rectangle is defined with edges parallel to the x-axis and y-axis relative to the local coordinate system. Rotation is about the point of origin. The `RectRound` is also used to represent a square shape with rounded corners. The characteristics of the square would be to have the width and height equal.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
RectRound	RectRoundType	A rectangle with one or more corners rounded. The user has the option to define any of the corners as containing the radius as well as the radiused dimensions. All corners (or opportunities for corners) must be identical in size.	1-1
width	nonNegativeDoubleType	The length of the rectangle about the x-axis.	1-1
height	nonNegativeDoubleType	The length of the rectangle about the y-axis.	1-1
radius	nonNegativeDoubleType	The radius to be trimmed from the four corners of the rectangle. It is an error to define a radius that is greater than ½ the height value or ½ the width value.	1-1
upperRight	boolean	The upper right corner (1).	0-1
upperLeft	boolean	The upper left corner (2).	0-1
lowerLeft	boolean	The lower left corner (3).	0-1
lowerRight	boolean	The lower right corner (4).	0-1



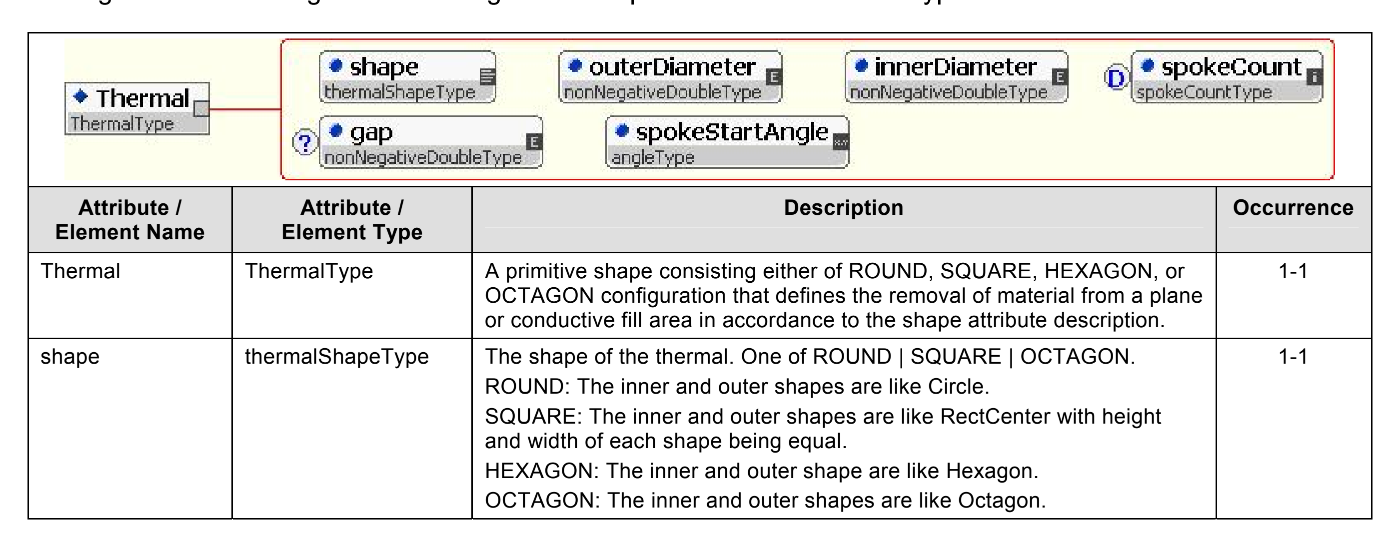

```
<EntryStandard id = "RoundedDshape1">
    <RectRound width = "10.2" height = "6.4" radius = "3.2"
        upperRight = "TRUE" lowerRight = "TRUE"/>
</EntryStandard>
```

```
<EntryStandard id = "RoundedDshape2">
    <RectRound width = "4.8" height = "4.8" radius = "2.4"
        upperRight = "TRUE" lowerRight = "TRUE"/>
</EntryStandard>
```

4.7.15 StandardPrimitive: Thermal

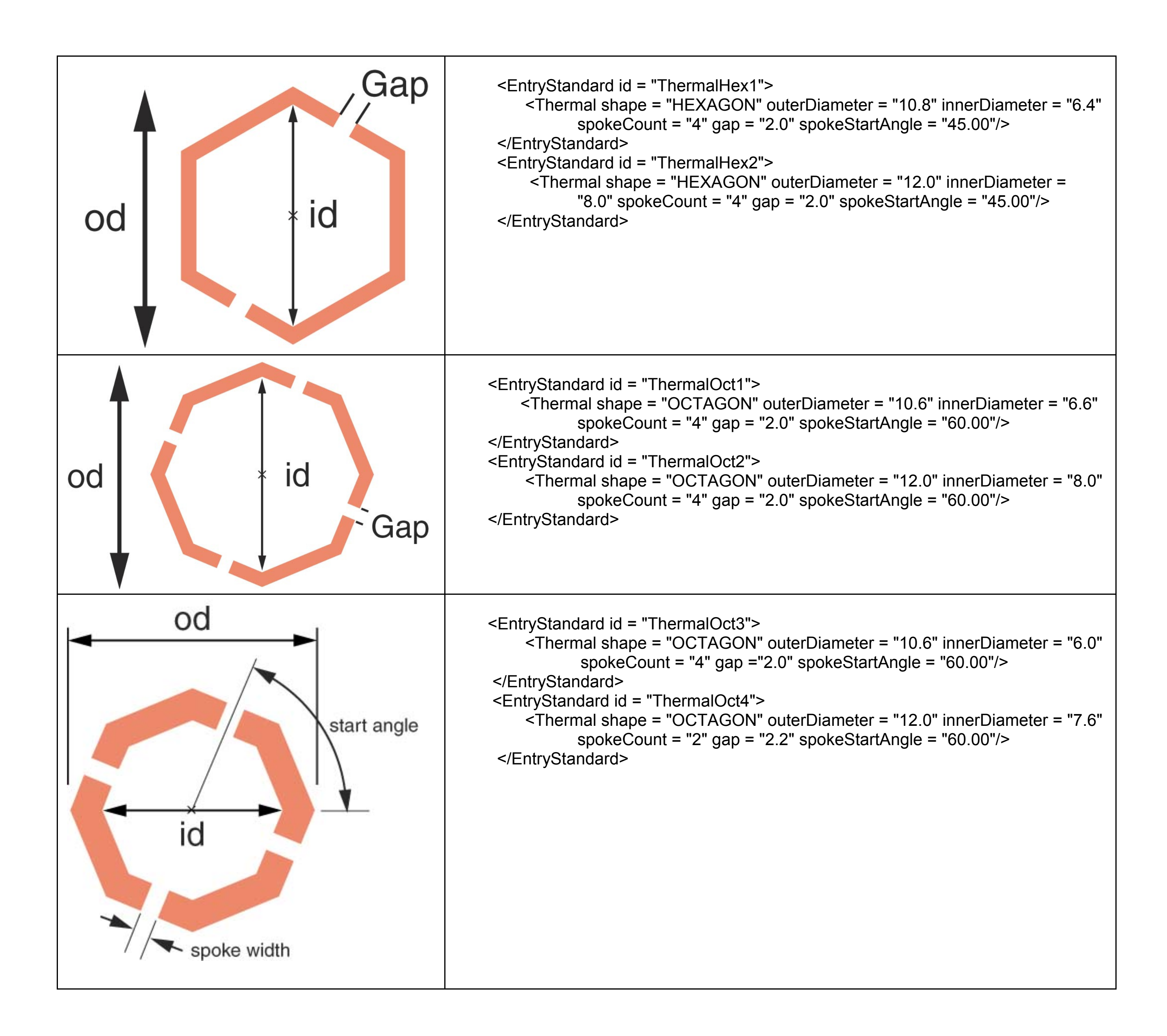
A `Thermal` is a `StandardPrimitive` shape that historically was used to remove material from a plane, conductive filled area or around a plated through hole. The `Thermal` shapes include square, round, hexagonal, or octagonal, and have varying numbers of spokes. The center of a thermal is the point of origin of the primitive.

A spokeless thermal can be used for non-functional lands on an innerlayer plane, where the land is not connected to the plane. IPC-2581 defines these using the `Thermal` element with a spoke count of zero. These are similar to a Donut except that they remove material. Many thermal primitive configurations can be generated using different spoke numbers and end types.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Thermal	ThermalType	A primitive shape consisting either of ROUND, SQUARE, HEXAGON, or OCTAGON configuration that defines the removal of material from a plane or conductive fill area in accordance to the shape attribute description.	1-1
shape	thermalShapeType	The shape of the thermal. One of ROUND | SQUARE | OCTAGON. ROUND: The inner and outer shapes are like Circle. SQUARE: The inner and outer shapes are like RectCenter with height and width of each shape being equal. HEXAGON: The inner and outer shape are like Hexagon. OCTAGON: The inner and outer shapes are like Octagon.	1-1

outerDiameter	nonNegativeDouble Type	The outer boundary of the filled region. The meaning based on the shape attribute: ROUND: The diameter of the circle is the outer boundary of the thermal. The center of the circle is at the origin of the thermal. SQUARE: The width along the x-axis and the height along the y-axis of a square at the inner boundary of the thermal. The center of the square is at the origin. HEXAGON: The point-to-point measurement (L) on the x-axis of the hexagon that forms the outer boundary of the thermal. OCTAGON: The point-to-point (L) measurement on the x-axis of the octagon that forms the outer boundary of the thermal.	1-1
innerDiameter	nonNegativeDouble Type	The inner boundary of the filled region. The meaning based on the shape attribute: ROUND: The diameter of the circle is the inner boundary of the thermal. The center of the circle is at the origin of the thermal. SQUARE: The width along the x-axis and the height along the y-axis of a square at the inner boundary of the thermal The center of the square is at the origin. HEXAGON: The point-to-point measurement on the x-axis of the hexagon that forms the inner boundary of the thermal. OCTAGON: The point-to-point measurement on the x-axis of the octagon that forms the inner boundary of the thermal.	1-1
spokeCount	spokeCountType	The number of cutouts allowed in the inner and outer shapes. ROUND: must be 0, 2, 3, or 4 (the default is 4) SQUARE: must be 0, 2, or 4 (the default is 4) HEXAGON: must be 0, 2, or 3 (the default is 3) OCTAGON: must be 0, 2, or 4 (the default is 4) If the `spokeCount` is defined as 0 (zero), the other three optional parameters do not apply. The spokeless thermal has a shape like a donut shape.	0-1
gap	nonNegativeDouble Type	The minimum distance between the sides of a spoke cut. The default value is the `innerDiameter` subtracted from the `outerDiameter`.	0-1
spokeStartAngle	angleType	The angle in counterclockwise direction from the x-axis at which the first spoke is cut. The default angle is 45º counterclockwise from the x-axis.	1-1
od id Gap		<EntryStandard id = "ThermalRound1"> <Thermal shape = "ROUND" outerDiameter = "10.6" innerDiameter = "6.0." spokeCount = "4" gap = "2.0" spokeStartAngle = "45.00"/> </EntryStandard> <EntryStandard id = "ThermalRound2"> <Thermal shape = "ROUND" outerDiameter = "12.0" innerDiameter = "8.0" spokeCount = "4" gap = "2.0" spokeStartAngle = "0.00"/> </EntryStandard>	
od id Gap		<EntryStandard id = "ThermalSquare1"> <Thermal shape = "SQUARE" outerDiameter = "10.8" innerDiameter = "6.0" spokeCount = "4" gap = "2.4" spokeStartAngle = "0.00"/> </EntryStandard> <EntryStandard id = "ThermalSquare2"> <Thermal shape = "SQUARE" outerDiameter = "12.8" innerDiameter = "8.0" spokeCount = "4" gap = "2.4" spokeStartAngle = "0.00"/> </EntryStandard>>	



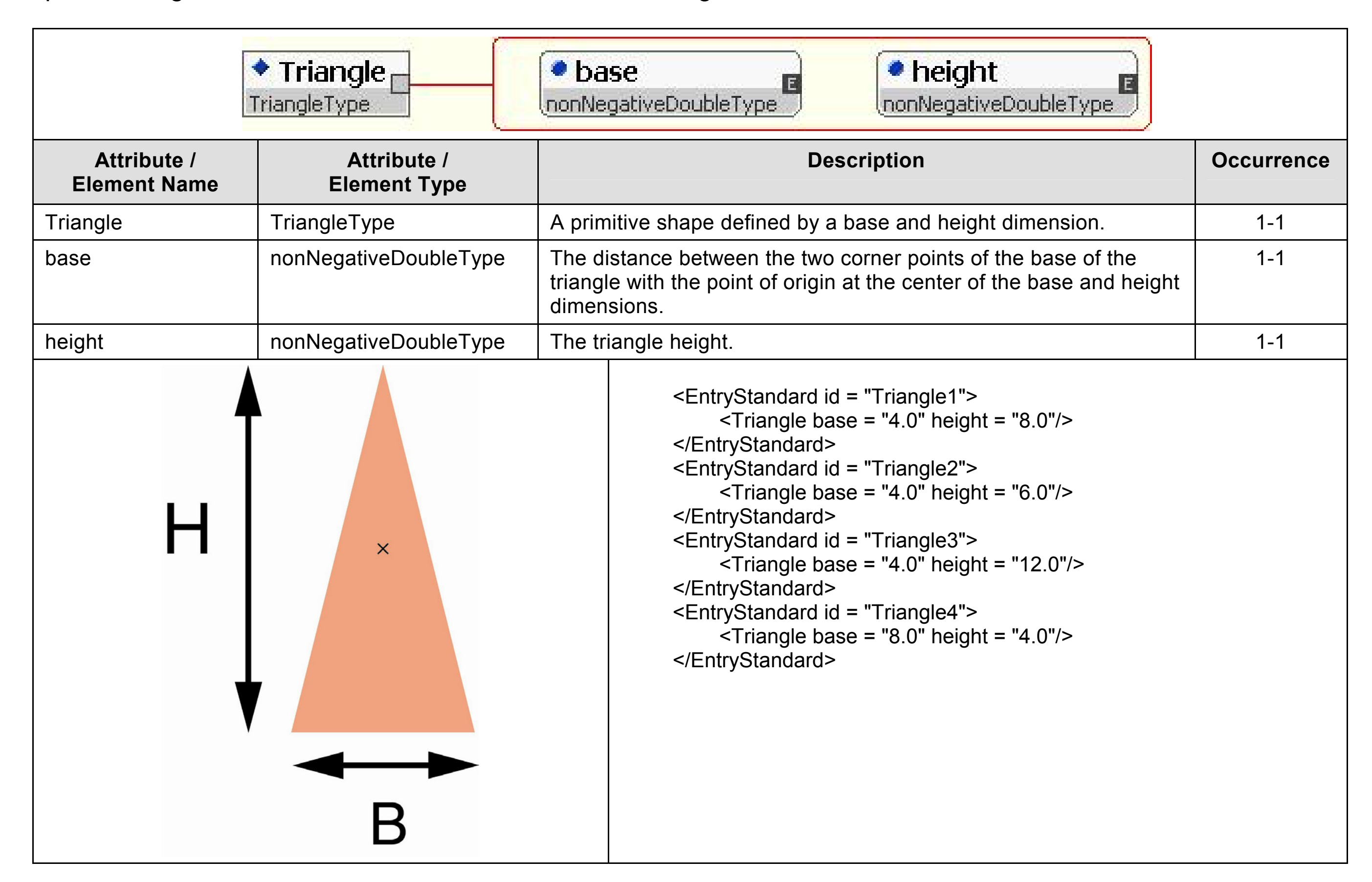

```
<EntryStandard id = "ThermalHex1">
    <Thermal shape = "HEXAGON" outerDiameter = "10.8" innerDiameter = "6.4"
        spokeCount = "4" gap = "2.0" spokeStartAngle = "45.00"/>
</EntryStandard>
<EntryStandard id = "ThermalHex2">
    <Thermal shape = "HEXAGON" outerDiameter = "12.0" innerDiameter =
        "8.0" spokeCount = "4" gap = "2.0" spokeStartAngle = "45.00"/>
</EntryStandard>
```

```
<EntryStandard id = "ThermalOct1">
    <Thermal shape = "OCTAGON" outerDiameter = "10.6" innerDiameter = "6.6"
        spokeCount = "4" gap = "2.0" spokeStartAngle = "60.00"/>
</EntryStandard>
<EntryStandard id = "ThermalOct2">
    <Thermal shape = "OCTAGON" outerDiameter = "12.0" innerDiameter = "8.0"
        spokeCount = "4" gap = "2.0" spokeStartAngle = "60.00"/>
</EntryStandard>
```

```
<EntryStandard id = "ThermalOct3">
    <Thermal shape = "OCTAGON" outerDiameter = "10.6" innerDiameter = "6.0"
        spokeCount = "4" gap ="2.0" spokeStartAngle = "60.00"/>
</EntryStandard>
<EntryStandard id = "ThermalOct4">
    <Thermal shape = "OCTAGON" outerDiameter = "12.0" innerDiameter = "7.6"
        spokeCount = "2" gap = "2.2" spokeStartAngle = "60.00"/>
</EntryStandard>
```

4.7.16 StandardPrimitive: Triangle

The `Triangle` is a `StandardPrimitive` shape that is an isosceles triangle that has two equal sides and a base. The shape is defined by the base and height dimension. The triangle is positioned with its point of origin which is at the center of the base and height dimensions.

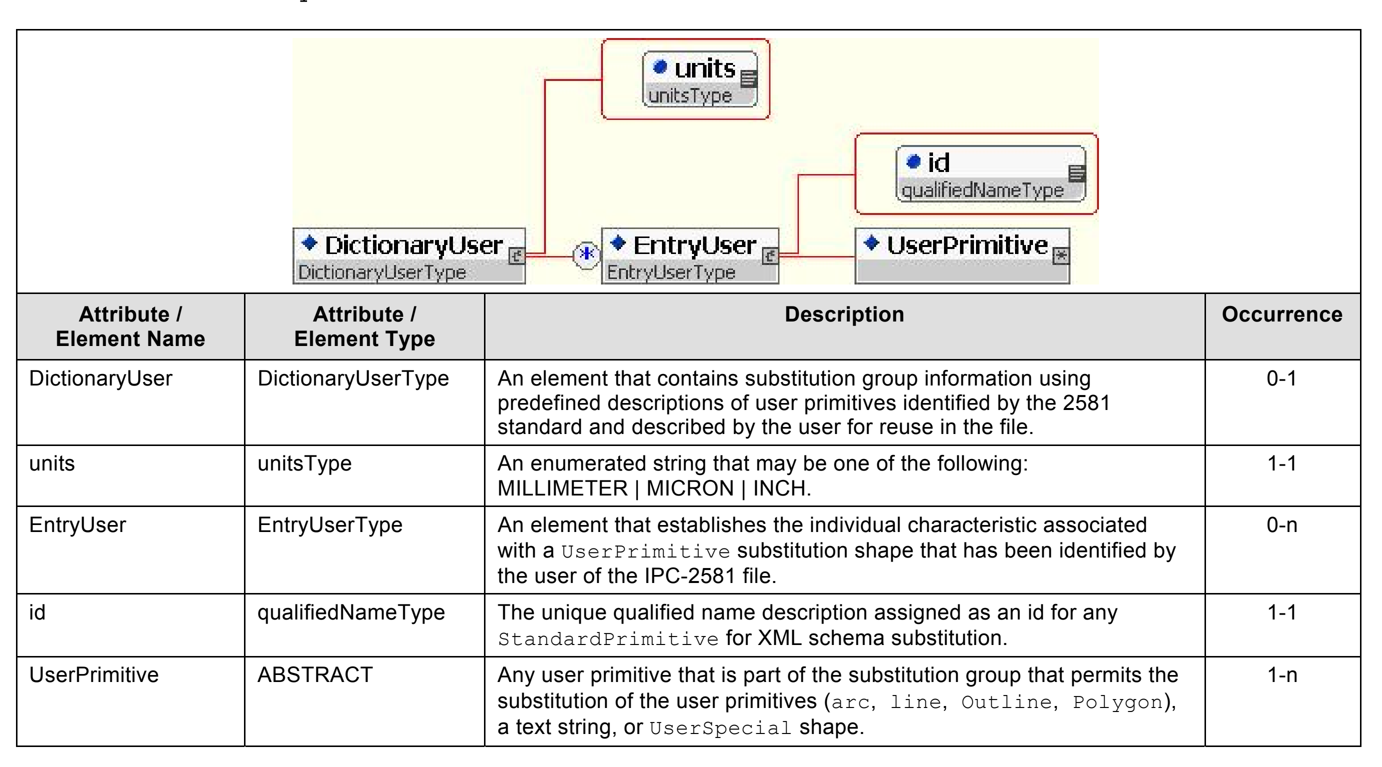


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Triangle	TriangleType	A primitive shape defined by a base and height dimension.	1-1
base	nonNegativeDoubleType	The distance between the two corner points of the base of the triangle with the point of origin at the center of the base and height dimensions.	1-1
height	nonNegativeDoubleType	The triangle height.	1-1

```
<EntryStandard id = "Triangle1">
    <Triangle base = "4.0" height = "8.0"/>
</EntryStandard>
<EntryStandard id = "Triangle2">
    <Triangle base = "4.0" height = "6.0"/>
</EntryStandard>
<EntryStandard id = "Triangle3">
    <Triangle base = "4.0" height = "12.0"/>
</EntryStandard>
<EntryStandard id = "Triangle4">
    <Triangle base = "8.0" height = "4.0"/>
</EntryStandard>
```

4.8 Content: DictionaryUser

The DictionaryUser is intended to provide lookup information on predefined UserPrimitives. The DictionaryUser is maintained as part of a substitution group schema. The intent is to have graphic descriptions available that are identified by their characteristics and a specific name (id). They may be reused throughout the file as appropriate. The name (id) of a UserPrimitive must be unique within the DictionaryUser.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryUser	DictionaryUserType	An element that contains substitution group information using predefined descriptions of user primitives identified by the 2581 standard and described by the user for reuse in the file.	0-1
units	unitsType	An enumerated string that may be one of the following: MILLIMETER | MICRON | INCH.	1-1
EntryUser	EntryUserType	An element that establishes the individual characteristic associated with a UserPrimitive substitution shape that has been identified by the user of the IPC-2581 file.	0-n
id	qualifiedNameType	The unique qualified name description assigned as an id for any StandardPrimitive for XML schema substitution.	1-1
UserPrimitive	ABSTRACT	Any user primitive that is part of the substitution group that permits the substitution of the user primitives (arc, line, Outline, Polygon), a text string, or UserSpecial shape.	1-n

The organization of the DictionaryUser is accomplished in accordance with the substitution group description criteria. The UserPrimitive description may be any of four simple shapes according to the specific characteristics identified in the following paragraphs plus text strings or user combinations of primitives to develop UserSpecial graphics for such items as logos, targets, drawing formats etc. The UserPrimitiveRef function is used in the body of the IPC-2581 file when a specific UserPrimitive has been predefined, assigned a name, and this unique “id” is referenced in the file. This feature permits the use of either a predefined UserPrimitive or defining the details of a UserPrimitive within the file. The description in the file must contain all the features of a particular primitive shape under the rules of the particular shape definition.

4.8.1 UserPrimitive, Simple

An abstract type identifying a substitution set of pre-defined simple primitive shapes that may be any one of four geometries. Each of the simple primitives must have a unique name within the DictionaryUser section. (See 3.4.9)

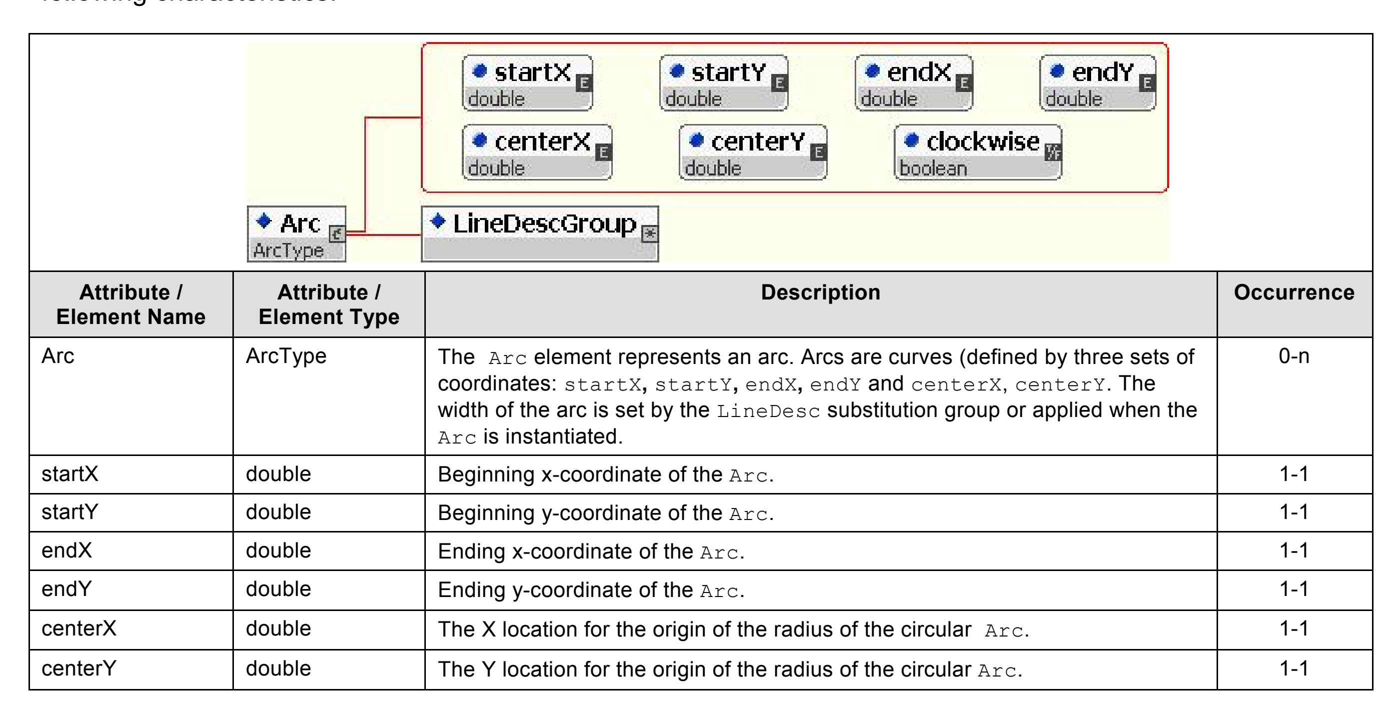
Simple

Arc Line Outline Polyline

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Arc	ArcType	The Arc element represents an arc. Arcs are curves (defined by three sets of coordinates: startX, startY, endX, endY, and centerX, centerY. The width of the arc is defined as a substitution group for LineDesc or applied when the Arc is instantiated.	0-n
Line	LineType	The Line element is used to describe an individual line segment. The lineWidth and lineEnd conditions are defined as a substitution group for LineDesc or applied when the line segment is instantiated. The lineEnd default is ROUND.	0-n
Outline	OutlineType	The Outline element is that of a Polygon and represents a closed shape. The point of origin of the shape is identified as the 0:0 coordinate. The element includes the start of the polygon definition (PolyBegin) and the appropriate number of PolySteps to complete the closed shape. The lineWidth is defined as a substitution group for LineDesc or applied when the Outline is instantiated.	0-n
Polyline	PolylineType	The Polyline element consists of a series of lines that define a particular grouping configuration. These line segments do not result in a closed shape, however they can be predefined and reused as needed. The lineWidth and lineEnd of the Polyline are defined as a substitution group for LineDesc or applied at the time the Polyline is instantiated.	0-n

4.8.1.1 UserPrimitive, Simple: Arc

Each Arc entry (EntryUser) in the DictionaryUser **shall** have a unique id and consist of the following characteristics:



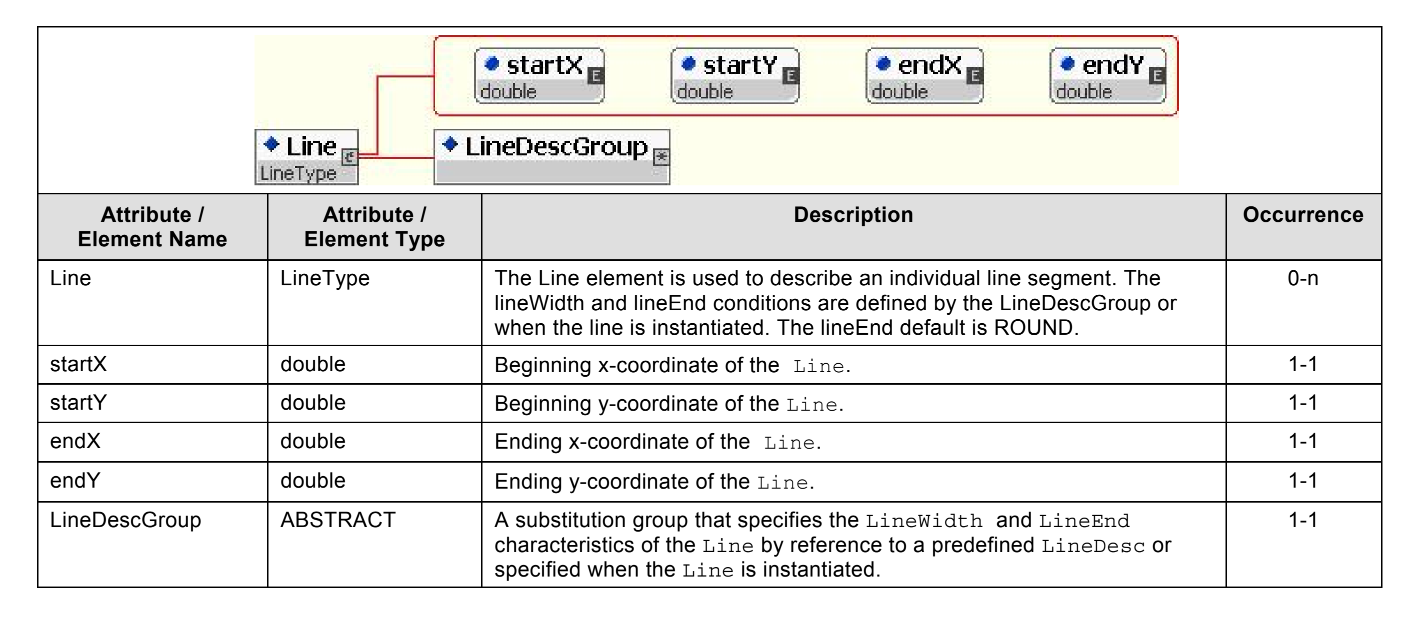
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Arc	ArcType	The Arc element represents an arc. Arcs are curves (defined by three sets of coordinates: startX, startY, endX, endY and centerX, centerY. The width of the arc is set by the LineDesc substitution group or applied when the Arc is instantiated.	0-n
startX	double	Beginning x-coordinate of the Arc.	1-1
startY	double	Beginning y-coordinate of the Arc.	1-1
endX	double	Ending x-coordinate of the Arc.	1-1
endY	double	Ending y-coordinate of the Arc.	1-1
centerX	double	The X location for the origin of the radius of the circular Arc.	1-1
centerY	double	The Y location for the origin of the radius of the circular Arc.	1-1

clockwise	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the `Arc` is in a `clockwise` direction; FALSE is the default indicating a counterclockwise direction.	0-1
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Arc` by reference to a predefined `LineDesc` or specified when the `Arc` is instantiated.	1-1

```
<EntryUser id = "Arc1">
      <Arc startX = "8.0" startY = "0.0" endX = "-8.0" endY = "0.0" centerX = "0.0" centerY = "0.0" clockwise = "FALSE">
        <LineDescRef id = "MediumLine"/>
    </Arc>
</EntryUser>
<EntryUser id = "Arc2">
    <Arc startX = "0.0" startY = "0.0" endX = "12.0" endY = "0.0" centerX = "6.0" centerY = "0.0" clockwise = "TRUE">
        <LineDescRef id = "HeavyLine"/>
    </Arc>
</EntryUser>
<EntryUser id = "Arc3">
    <Arc startX = "-8.0" startY = "0.0" endX = "0.0" endY = "8.0" centerX = "0.0" centerY = "0.0" clockwise = "TRUE">
        <LineDesc lineEnd = "ROUND" lineWidth = "1.0"/>
    </Arc>
 </EntryUser>
```

4.8.1.2 UserPrimitive, Simple: Line

Each `Line` entry (`EntryUser`) in the `DictionaryUser` **shall** have a unique id and consist of the following characteristics:

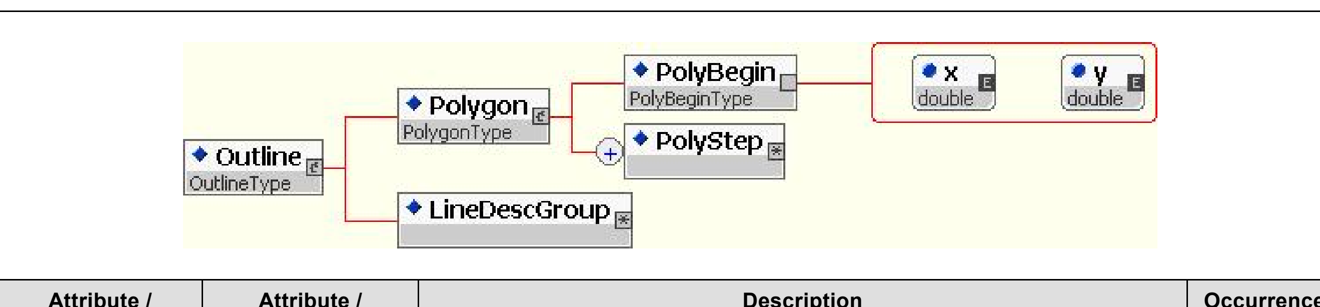


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Line	LineType	The Line element is used to describe an individual line segment. The lineWidth and lineEnd conditions are defined by the LineDescGroup or when the line is instantiated. The lineEnd default is ROUND.	0-n
startX	double	Beginning x-coordinate of the `Line`.	1-1
startY	double	Beginning y-coordinate of the `Line`.	1-1
endX	double	Ending x-coordinate of the `Line`.	1-1
endY	double	Ending y-coordinate of the `Line`.	1-1
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Line` by reference to a predefined `LineDesc` or specified when the `Line` is instantiated.	1-1

```
<EntryUser id = "Line1">
   <Line startX = "0.0" startY = "0.0" endX = "12.6" endY = "9.4">
      <LineDesc lineEnd = "ROUND" lineWidth = "1.0"/>
   </Line>
</EntryUser>
<EntryUser id = "Line2">
   <Line startX = "3.6" startY = "4.8" endX = "-4.8" endY = "-3.6">
      <LineDescRef id = "MediumLine"/>
   </Line>
</EntryUser>
<EntryUser id = "Line3">
   <Line startX = "0.0" startY = "0.0" endX = "12.8" endY = "0.0">
      <LineDescRef id = "HeavyLine"/>
   </Line>
</EntryUser>
<EntryUser id = "Line4">
   <Line startX = "12.8" startY = "2.4" endX = "-10.2" endY = "1.2">
      <LineDesc lineEnd = "SQUARE" lineWidth = "0.8"/>
   </Line>
</EntryUser>
```

4.8.1.3 UserPrimitive, Simple: Outline

Each `Outline` entry (`EntryUser`) in the `DictionaryUser` **shall** have a unique id and consist of the following characteristics. The `Outline` element consists of the following characteristics using a `Polygon` shape to represent a closed shaped group of lines.

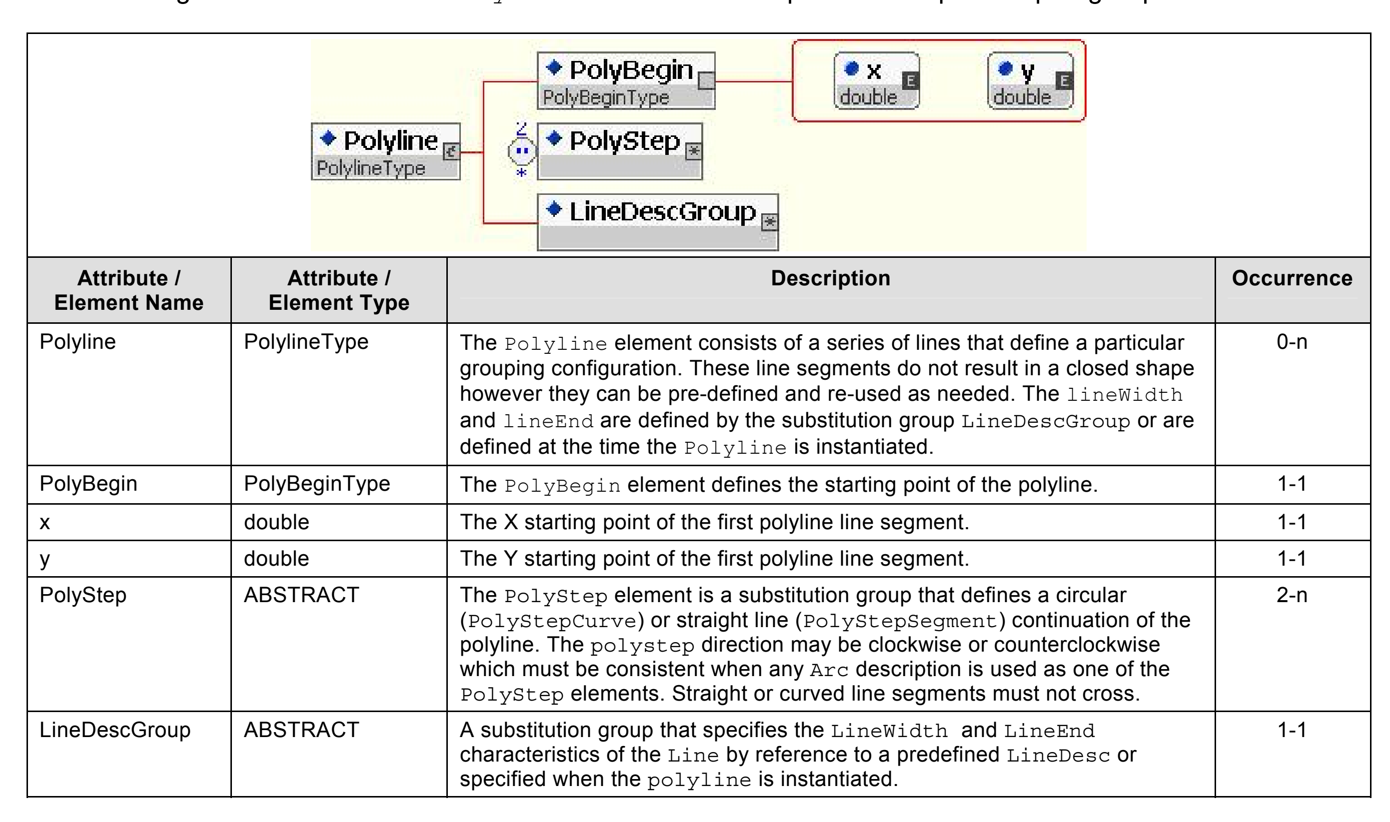


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Outline	OutlineType	An element that has as its sub elements the `Polygon` and `LineDesc` elements in order to define a closed shape that has a line width.	0-n
Polygon	PolygonType	The standard description for the `Polygon` characteristic must be a closed shape. The point of origin of the shape is identified as the 0:0 coordinate. The element includes the start of the polygon definition (`PolyBegin`) and the appropriate number of PolySteps to complete the closed shape. The lineWidth is through the `LineDesc` substitution group or defined at a time when the `Polygon` is instantiated.	0-n
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon line.	1-1
y	double	The Y starting point of the first polygon line.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the `PolyBegin` element to signify that the shape is closed.	2-n
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Line` by reference to a predefined `LineDesc` or specified when the Outl`ine` is instantiated.	1-1

```
<EntryUser id = "Outline1">
   <Outline>
      <Polygon>
         <PolyBegin x = "0.0" y = "6.4"/>
         <PolyStepSegment x = "12.6" y = "6.4"/>
         <PolyStepCurve x = "14.8" y = "4.2" centerX = "12.6" centerY = "4.2" clockwise = "TRUE"/>
         <PolyStepSegment x = "14.8" y = "0.0"/>
         <PolyStepSegment x = "0.0" y = "0.0"/>
         <PolyStepSegment x = "0.0" y = "6.4"/>
      </Polygon>
      <LineDescRef id = "FineLine"/>
   </Outline>
</EntryUser>
<EntryUser id = "Outline2">
   <Outline>
      <Polygon>
         <PolyBegin x = "-10.4" y = "-2.0"/>
         <PolyStepSegment x = "-10.4" y = "0.0"/>
         <PolyStepCurve x = "10.4" y = "0.0" centerX = "0.0" centerY = "0.0" clockwise = "TRUE"/>
         <PolyStepSegment x = "10.4" y = "-2.0"/>
         <PolyStepSegment x = "0.0" y = "-6.0"/>
         <PolyStepSegment x = "-10.4" y = "-2.0"/>
      </Polygon>
      <LineDesc lineEnd = "ROUND" lineWidth = "0.2"/>
   </Outline>
</EntryUser>
```

4.8.1.4 UserPrimitive, Simple: PolyLine

Each `PolyLine` entry (`Entryuser`) in the `DictionaryUser` **shall** have a unique id and consist of the following characteristics. The `PolyLine` characteristics represent an open shaped group of lines.



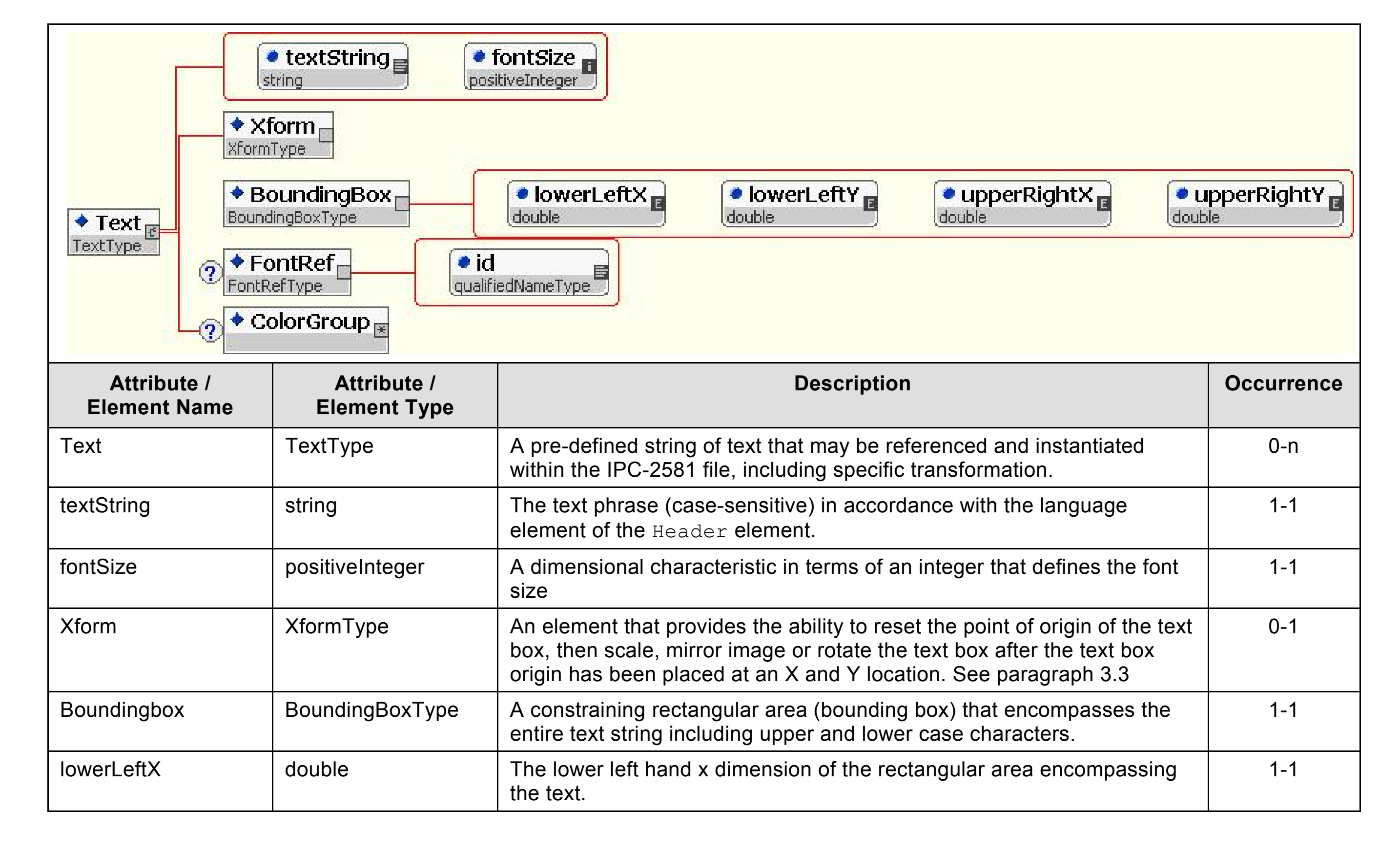
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Polyline	PolylineType	The `Polyline` element consists of a series of lines that define a particular grouping configuration. These line segments do not result in a closed shape however they can be pre-defined and re-used as needed. The `lineWidth` and `lineEnd` are defined by the substitution group `LineDescGroup` or are defined at the time the `Polyline` is instantiated.	0-n
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polyline.	1-1
x	double	The X starting point of the first polyline line segment.	1-1
y	double	The Y starting point of the first polyline line segment.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polyline. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross.	2-n
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Line` by reference to a predefined `LineDesc` or specified when the `polyline` is instantiated.	1-1

```
<EntryUser id = "Polyline1">
    <Polyline>
        <PolyBegin x = "0.0" y = "0.0"/>
        <PolyStepSegment x = "4.0" y = "0.0"/>
        <PolyStepCurve x = "4.0" y = "6.0" centerX = "4.0" centerY = "3.0" clockwise = "FALSE"/>
        <PolyStepCurve x = "4.0" y = "12.0" centerX = "4.0" centerY = "9.0" clockwise = "TRUE"/>
        <LineDescRef id = "HeavyLine"/>
    </Polyline>
</EntryUser>
<EntryUser id = "Polyline2">
    <Polyline>
        <PolyBegin x = "3.2" y = "2.2"/>
        <PolyStepSegment x = "8.8" y = "10.4"/>
        <PolyStepCurve x = "8.8" y = "16.4" centerX = "8.8" centerY = "13.4" clockwise = "TRUE"/>
        <PolyStepSegment x = "6.0" y = "16.4"/>
        <PolyStepSegment x = "6.0" y = "10.0"/>
        <LineDesc lineEnd = "ROUND" lineWidth = "0.5"/>
    </Polyline>
</EntryUser>
```

4.8.2 UserPrimitive: Text

When text is to be drawn on a product or a drawing the definition includes a bounding rectangle for the text. The lowerLeftX and lowerLeftY coordinate and the upperRightX and upperRightY coordinate define the BoundingBox rectangle. All portions of the text, including the line width of the strokes of the text, must fit within the BoundingBox rectangle. Any portion of a character exceeding the perimeter of the BoundingBox rectangle will be clipped at the boundaries of the BoundingBox rectangle.

Each Text entry (EntryUser) in the DictionaryUser **shall** have a unique id and consist of the following characteristics:



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Text	TextType	A pre-defined string of text that may be referenced and instantiated within the IPC-2581 file, including specific transformation.	0-n
textString	string	The text phrase (case-sensitive) in accordance with the language element of the Header element.	1-1
fontSize	positiveInteger	A dimensional characteristic in terms of an integer that defines the font size	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of the text box, then scale, mirror image or rotate the text box after the text box origin has been placed at an X and Y location. See paragraph 3.3	0-1
Boundingbox	BoundingBoxType	A constraining rectangular area (bounding box) that encompasses the entire text string including upper and lower case characters.	1-1
lowerLeftX	double	The lower left hand x dimension of the rectangular area encompassing the text.	1-1

lowerLeftY	double	The lower left hand y dimension of the rectangular area encompassing the text.	1-1
UpperRightX	double	The upper right hand x dimension of the the rectangular area encompassing the text.	1-1
UpperRightY	double	The upper right hand y dimension of the rectangular area encompassing the text.	1-1
FontRef	FontRefType	An element that is optional to reference a predefined font by its id, if the standard Helvetica font is not being instantiated.	0-1
id	qualifiedNameType	The identification of the `FontDef` stored in the `DictionaryFont.`	1-1
ColorGroup	ABSTRACT	An optional substitution group that permits assigning a particular color through instantiating the three basic colors or by providing a reference to a predefined `Color` in `DictionaryColor.`	0-1

The following diagram and the requirments describe the general case for how text is to be drawn. There are two variations on the use of text. This makes `Text` an element that is incorporated as a layer feature or in a `Package` description. When used in this manner, all the characteristics of `Xform` and the `BoundingBox` apply. The other form of text is as a simple `string` attribute. This is where the word `text` is used to add extra information to a particular element and therefore does not require the special features for `location`, `font`, and `Xform`.

When `text` is used as an element, the attribute `textString` should be defined to be enclosed in the textbox as illustrated in Figure 4. This includes upper and lower case letters, as well as all line widths, line descriptions, and line ends. Anything outside the clipping box will be clipped. The clipping boundary is necessary because fonts vary between computer systems and application implementations.

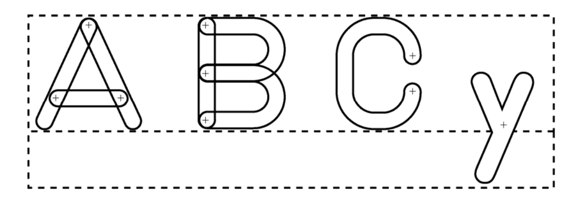


Figure 4 Bounding rectangle to round end character relationships

4.8.2.1 Text restrictions

Text character dimensions are constrained by the bounding rectangle as illustrated in Figure 5. Character height is expressed by the `fontSize` attribute. Incremental units of the `BoundingBox` follow the `Units` element used by the file; this sets the limits (left and right xy coordinates) of the bounding rectangle. Both upper and lower case letters must be inside the `BoundingBox` rectangle. Included in this requirement are the extensions of such descending letters as lower case “g,” “q,” “y,” “j,” and “p.”

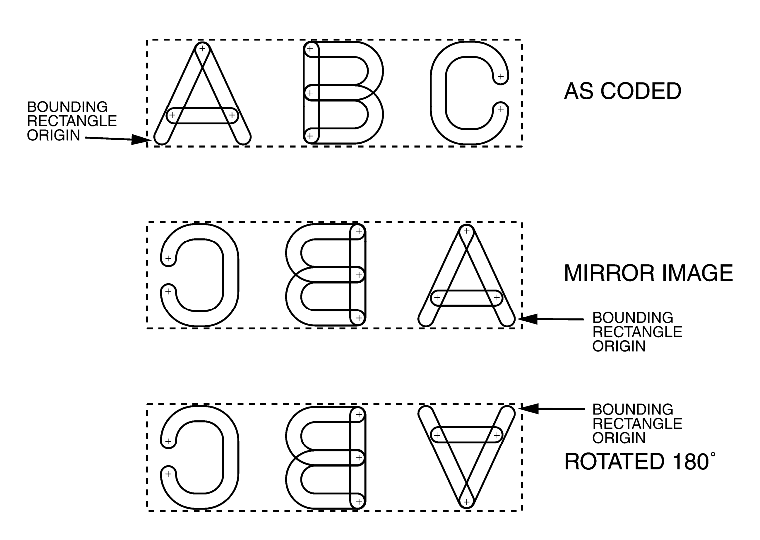


Figure 5 Text transformation examples

4.8.2.2 Text rotation

The bounding rectangle of `Text` is defined relative to the local coordinate system. The `xLocation` and `yLocation` of `Xform` is applied to the bounding rectangle and the text contained within the rectangle to locate the `Text`. The bounding rectangle must be mirrored if required before it is rotated. The text is drawn relative to the bounding rectangle.

The example shown in Figure 6 indicates a `BoundingBox` rectangle that has been rotated 30° about the lower left xy coordinate.

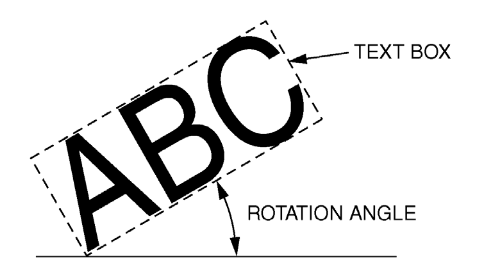


Figure 6 Rotation Angle

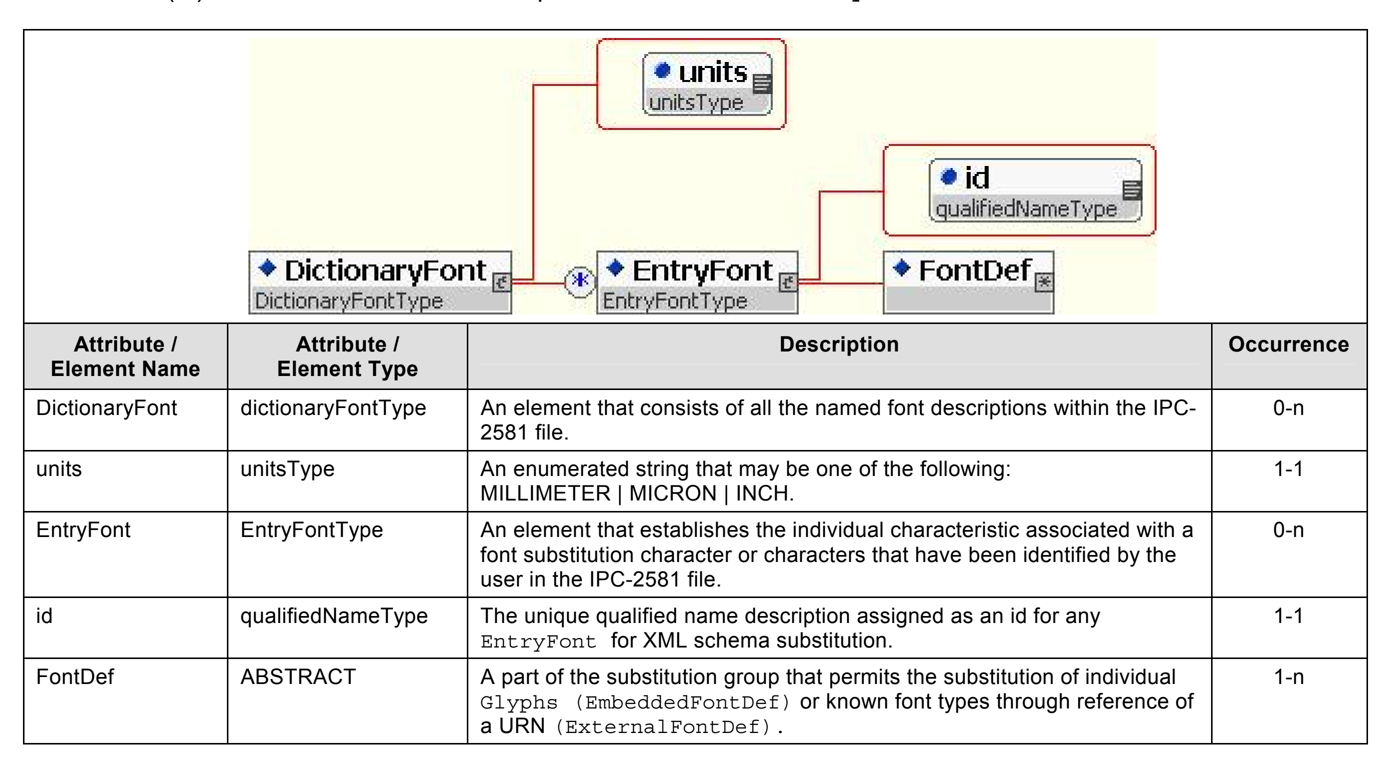
4.8.3 UserPrimitive: UserSpecial

Each `UserSpecial` entry (`EntryUser`) in the `DictionaryUser` **shall** have a unique id and consist of the following characteristics. The `UserSpecial` may be any combination of `StandardShapes` or `UserShapes`, and is used to develop logos, targets, drawing formats or other combination of shapes.

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
UserSpecial	UserSpecialType	A combination of primitive shapes that may be organized in any orientation needed to represent the users needs for defining a special graphic shape.	0-n
Feature	ABSTRACT	A substitution group consisting of any graphic allowed by either the `StandardShape` or `UserShape` substitution groups.	0-n
StandardShape	ABSTRACT	A substitution group that permits the substitution of the `StandardShape` element. The `StandardShape` element may be used to further classify `Feature.` In so doing, `StandardShape` can be substituted by a `StandardPrimitive` or `StandardPrimitiveRef.`	0-n
UserShape	ABSTRACT	A substitution group that permits the substitution or classification of a higher level substitution group. The `UserShape` element may be used to further classify `Feature.` In so doing, `UserShape` can be substituted by a `UserPrimitive` or `UserPrimitiveRef.`	0-n

4.9 Content: DictionaryFont

The `DictionaryFont` is intended to provide lookup information on predefined font descriptions when the standard Helvetica font is not used. The `DictionaryFont` is maintained as part of a substitution group schema. The intent is to have font descriptions available that are identified by their characteristics and a specific name (id). The reference is to individual `Glyph` characters or to a known font through reference to a URN. Font descriptions may be reused throughout the file as appropriate. The name (id) of a `FontDef` must be unique within the `DictionaryFont.`



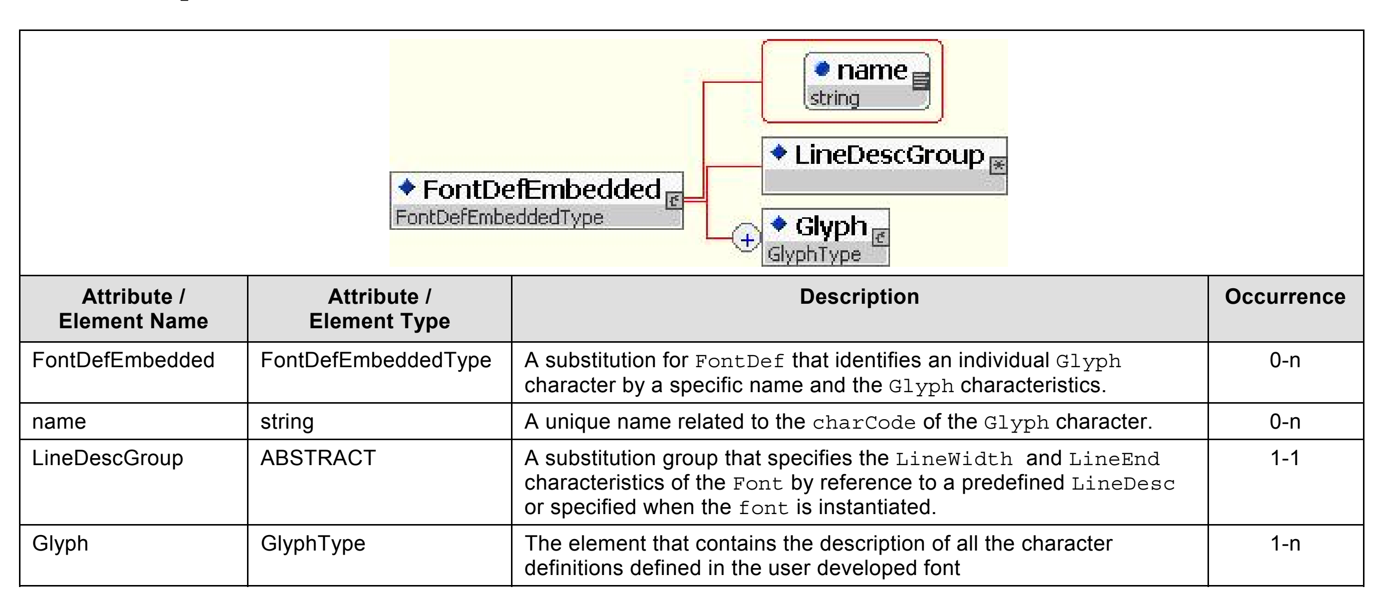
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryFont	dictionaryFontType	An element that consists of all the named font descriptions within the IPC-2581 file.	0-n
units	unitsType	An enumerated string that may be one of the following: MILLIMETER | MICRON | INCH.	1-1
EntryFont	EntryFontType	An element that establishes the individual characteristic associated with a font substitution character or characters that have been identified by the user in the IPC-2581 file.	0-n
id	qualifiedNameType	The unique qualified name description assigned as an id for any `EntryFont` for XML schema substitution.	1-1
FontDef	ABSTRACT	A part of the substitution group that permits the substitution of individual `Glyphs (EmbeddedFontDef)` or known font types through reference of a URN `(ExternalFontDef).`	1-n

The organization of the `Dictionaryfont` is accomplished in accordance with the substitution group description criteria. The `FontDef` description may be any character represented as a `Glyph` according to the specific characteristics identified in the following paragraphs. `FontDef` may also be a know font

through reference of a URN. The FontRef function is used in the body of the IPC-2581 file when a specific font has been predefined, assigned a name, and the unique "id" is referenced in the file. This feature permits the substitution of the standard Helvetica font; Font descriptions are only contained in the DictionaryFont and are not instantiated in the body of the IPC-2581 file.

4.9.1 FontDefEmbedded

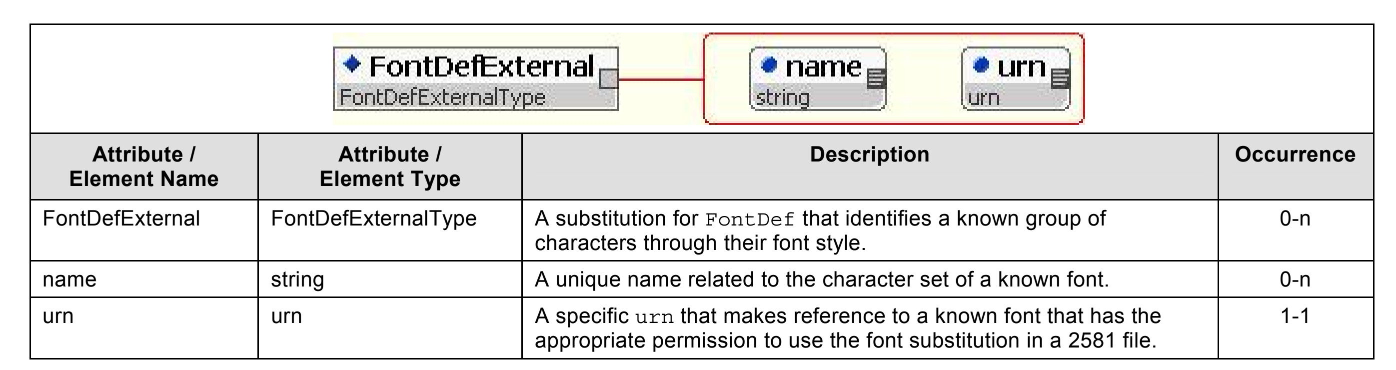
The FontDefEmbedded element is used to capture individual characters and store them in the DictionaryFont.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FontDefEmbedded	FontDefEmbeddedType	A substitution for FontDef that identifies an individual Glyph character by a specific name and the Glyph characteristics.	0-n
name	string	A unique name related to the charCode of the Glyph character.	0-n
LineDescGroup	ABSTRACT	A substitution group that specifies the LineWidth and LineEnd characteristics of the Font by reference to a predefined LineDesc or specified when the font is instantiated.	1-1
Glyph	GlyphType	The element that contains the description of all the character definitions defined in the user developed font	1-n

4.9.2 FontDefExternal

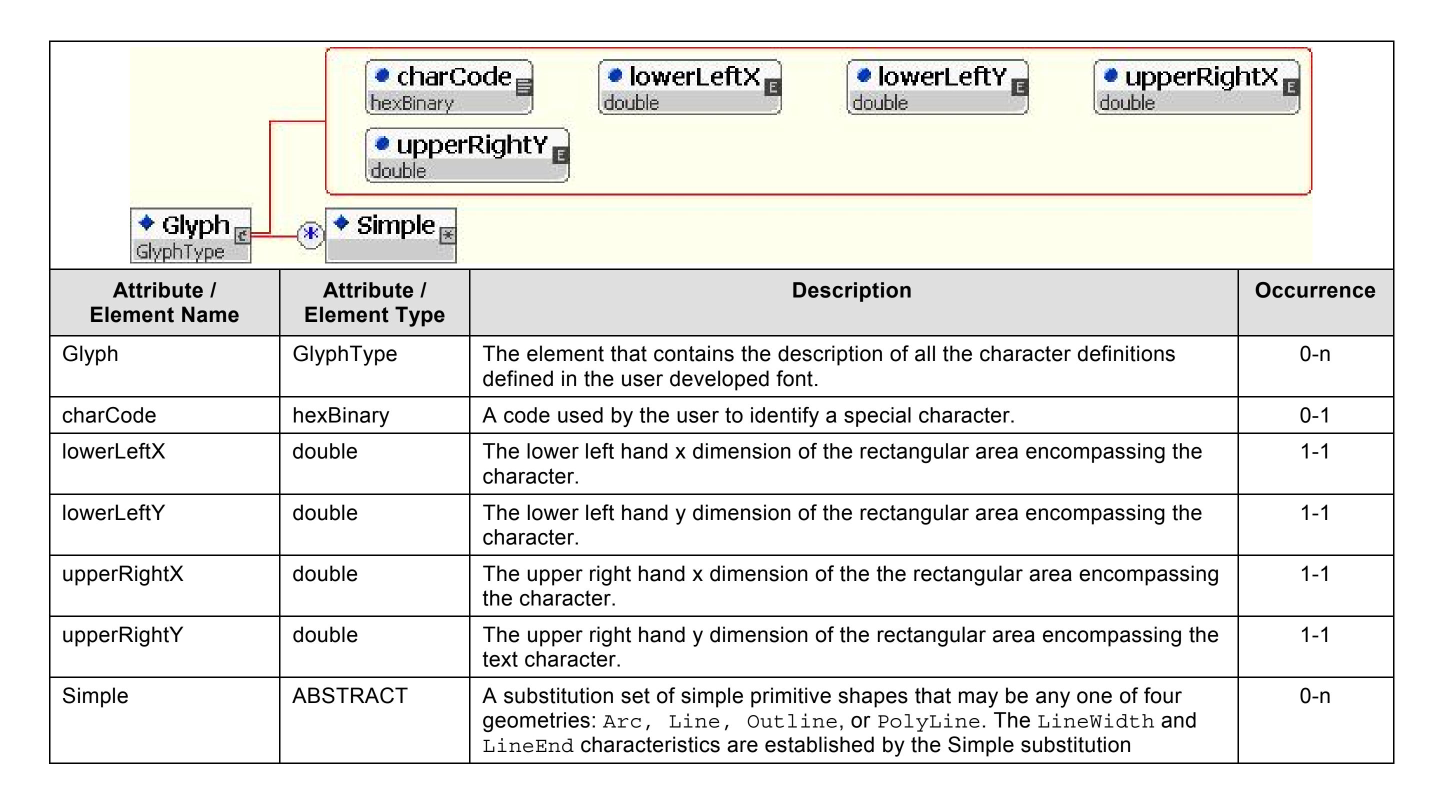
The FontDefExternal element is used to capture known font characters and store the reference in the DictionaryFont.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FontDefExternal	FontDefExternalType	A substitution for FontDef that identifies a known group of characters through their font style.	0-n
name	string	A unique name related to the character set of a known font.	0-n
urn	urn	A specific urn that makes reference to a known font that has the appropriate permission to use the font substitution in a 2581 file.	1-1

4.9.3 FontDef: Glyph

The Glyph character set is a group of user defined characters that will be reference by the text command in the file. Glyph permits the user to define a special set of characters that need description as a part of the IPC-2581 file. Each character is in a BoundingBox that contains all the line strokes needed to completely define each character in the set. The point of origin is the lower left hand corner of the BoundingBox. The lowerLeftX and lowerLeftY point of origin will be used to position, rotate or mirror image all Glyph characters.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Glyph	GlyphType	The element that contains the description of all the character definitions defined in the user developed font.	0-n
charCode	hexBinary	A code used by the user to identify a special character.	0-1
lowerLeftX	double	The lower left hand x dimension of the rectangular area encompassing the character.	1-1
lowerLeftY	double	The lower left hand y dimension of the rectangular area encompassing the character.	1-1
upperRightX	double	The upper right hand x dimension of the the rectangular area encompassing the character.	1-1
upperRightY	double	The upper right hand y dimension of the rectangular area encompassing the text character.	1-1
Simple	ABSTRACT	A substitution set of simple primitive shapes that may be any one of four geometries: `Arc, Line, Outline`, or `PolyLine`. The `LineWidth` and `LineEnd` characteristics are established by the Simple substitution	0-n

4.9.4 FontDef: Glyph combination

The developers of individual `Glyph` characters are encouraged to consider the manner in which the characters will be used. Since the `BoundingBox` surrounding the character must entirely encompass the `Glyph`, it is important to leave room in the `BoundingBox` so that the spacing between characters is consistent with the character style.

Using individual `Glyph` characters does not present a problem, however `Glyph` combinations should match the style of `Glyph` chosen by the user. Since it is mostly the `Text` element that instantiates fonts, the `Glyph BoundingBox` must fit into the `Text BoundingBox`. This is a simple strategy when all the `Glyph` characters are of a similar height. In this instance the “Y” dimensional differences between `Glyph` characters bounding boxes and `Text` bounding boxes should be identical in order to keep the `Glyph` characters within the `Text` box. Under those circumstances, only the spacing between characters needs to be considered.

As an example consider the word simple instantiated in capital letters or lower case. When instantiating a `Text` string, the `Glyph` for “SIMPLE” would only require equal bounding boxes in the character height even though the character “I” would have a smaller character width than the character “M”. A different strategy for `Glyph` development must be used if the `Text` string were to call for “Simple”. Since character height is different, it is recommended that the `Glyph BoundingBox` consider its location position in a `Text BoundingBox` according to the rule that all characters must be inside the `Text` box.

Figure 7 shows and example of `Glyph` bounding boxes related to the `Text BoundingBox`. The characters line up even though they are positioned on the lower y-coordinate. They were designed along a construction line to have this condition occur.

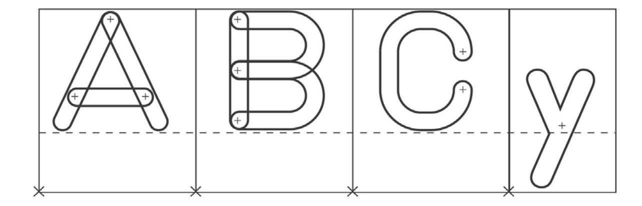


Figure 7 Glyph bounding rectangles to Text bounding box relationships

4.10 Content: DictionaryLineDesc

The `DictionarylineDesc` is intended to provide lookup information on predefined line descriptions. The `DictionarylineDesc` is maintained as part of a substitution group schema. The intent is to have line descriptions available that are identified by their characteristics and a specific name (id). They may be reused throughout the file as appropriate. The name (id) of a `LineDesc` must be unique within the `DictionaryLineDesc.`

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryLineDesc	DictionaryLineDesc Type	An element that contains substitution group information using line description criteria, predefined by the user for reuse in the file.	0-1
units	unitsType	An enumerated string that may be one of the following: MILLIMETER | MICRON | INCH.	1-1
EntryLineDesc	EntryLineDescType	An element that establishes the individual characteristic associated with a line description substitution group that has been identified by the user of the IPC-2581 file.	0-n
id	qualifiedNameType	The unique qualified name description assigned as an id for any `LineDesc` for XML schema substitution.	1-1
LineDesc	LineDescType	An element that defines the `LineEnd` and `LineWidth` characteristics to become part of the substitution group for defining line descriptions.	1-n

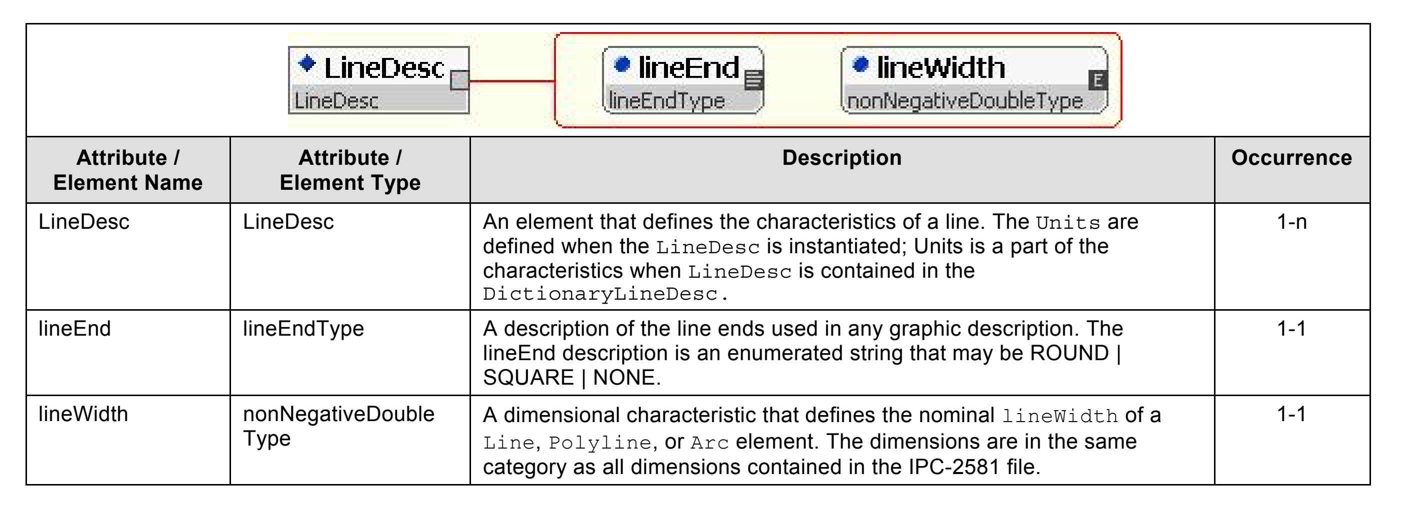
```
<DictionaryLineDesc units = "MILLIMETER">
    <EntryLineDesc id = "FineLine">
        <LineDesc lineEnd = "ROUND" lineWidth = "0.05"/>
    </EntryLineDesc>
    <EntryLineDesc id = "MediumLine">
        <LineDesc lineEnd = "NONE" lineWidth = "0.15"/>
    </EntryLineDesc>
        <EntryLineDesc id = "HeavyLine">
        <LineDesc lineEnd = "SQUARE" lineWidth = "0.30"/>
    </EntryLineDesc>
</DictionaryLineDesc>
```

The organization of the `DictionaryLineDesc` is accomplished in accordance with the substitution group description criteria. The `lineDesc` description defines the `LineEnd` and `LineWidth` according to the specific characteristics identified in the following paragraphs. The `LineDescRef` function is used in the body of the IPC-2581 file when a specific `LineDesc` has been predefined, assigned a name, and the unique "id" is referenced in the file. This feature permits the use of either a predefined `LineDesc`,

or defining the details of a LineDesc within the file. The description in the file must contain all the features of a line description under the rules of the LineDesc definition.

4.10.1 LineDesc

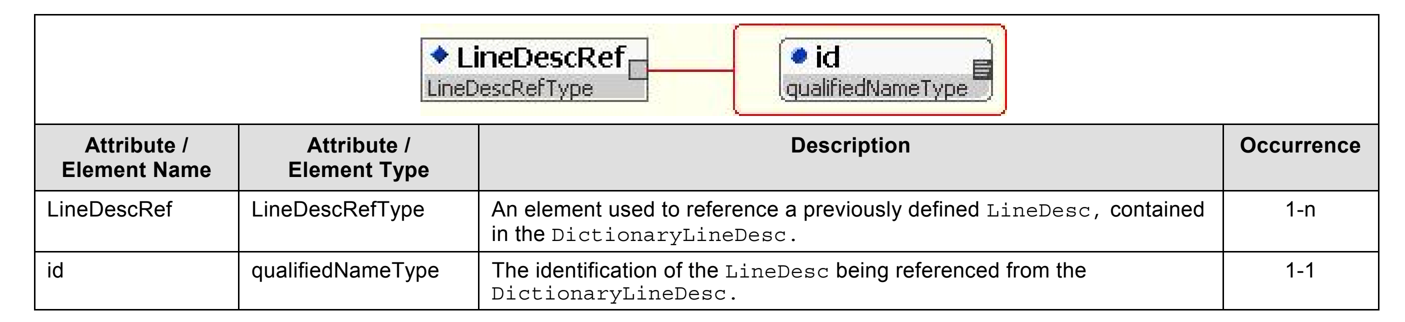
The LineDesc element is used throughout the 2581 file to establish the characteristics of lineEnd and lineWidth descriptions. The LineDesc definition is according to the following characteristics.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LineDesc	LineDesc	An element that defines the characteristics of a line. The Units are defined when the LineDesc is instantiated; Units is a part of the characteristics when LineDesc is contained in the DictionaryLineDesc.	1-n
lineEnd	lineEndType	A description of the line ends used in any graphic description. The lineEnd description is an enumerated string that may be ROUND | SQUARE | NONE.	1-1
lineWidth	nonNegativeDouble Type	A dimensional characteristic that defines the nominal lineWidth of a Line, Polyline, or Arc element. The dimensions are in the same category as all dimensions contained in the IPC-2581 file.	1-1

4.10.2 LineDescRef

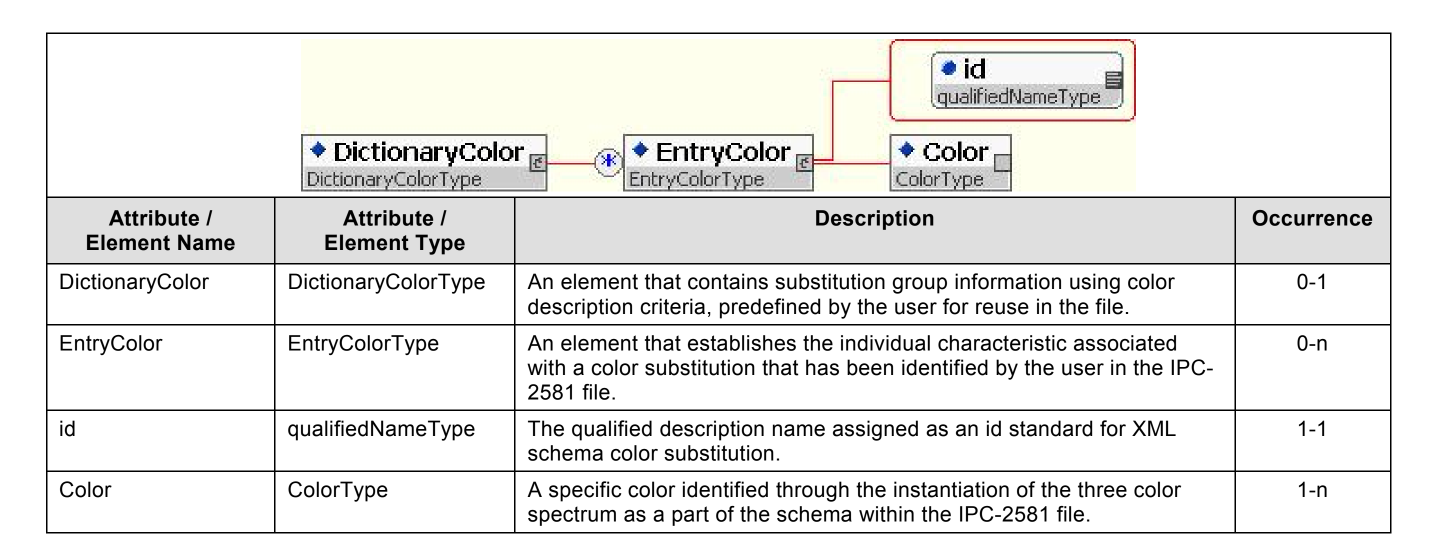
The LineDescRef element is used throughout the 2581 file to establish the relationship to a previously defined LineDesc. The Units of the predefined LineDesc must match the Units of the Ecad section in which it is instantiated. The LineDescRef definition is according to the following characteristics.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LineDescRef	LineDescRefType	An element used to reference a previously defined LineDesc, contained in the DictionaryLineDesc.	1-n
id	qualifiedNameType	The identification of the LineDesc being referenced from the DictionaryLineDesc.	1-1

4.11 Content: DictionaryColor

The DictionaryColor is intended to provide lookup information on predefined Color descriptions. The DictionaryColor is maintained as part of a substitution group schema. The intent is to have color descriptions available that are identified by their three color hues and intensity characteristics and a specific name (id). They may be reused throughout the file as appropriate. The name (id) of a color must be unique within the DictionaryColor.

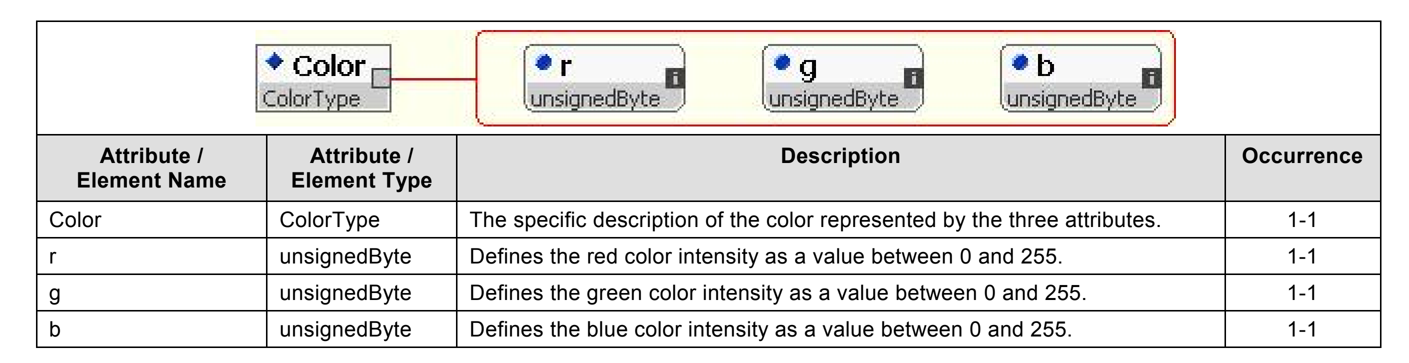


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryColor	DictionaryColorType	An element that contains substitution group information using color description criteria, predefined by the user for reuse in the file.	0-1
EntryColor	EntryColorType	An element that establishes the individual characteristic associated with a color substitution that has been identified by the user in the IPC-2581 file.	0-n
id	qualifiedNameType	The qualified description name assigned as an id standard for XML schema color substitution.	1-1
Color	ColorType	A specific color identified through the instantiation of the three color spectrum as a part of the schema within the IPC-2581 file.	1-n

The organization of the `DictionaryColor` is accomplished in accordance with the substitution group description criteria. The `Color` description may be any combination of the three color hues (red, green and blue) at the appropriate intensity according to the specific characteristics identified in the following paragraphs. The `colorRef` function is used in the body of the IPC-2581 file when a specific `Color` has been predefined, assigned a name, and the unique "id" is referenced in the file. This feature permits the use of either a predefined `Color`, or defining the details of a `Color` within the file. The description in the file must contain all the features of a particular `Color` under the rules of the particular `color` definition.

4.11.1 Color

`Color` is defined by three values that represent the red, green and blue components of the composite color. If r, g, and b are all set to 0, the color is black. If all values are 255 then the color is white. The attributes of a `Color` element are defined as follows:



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Color	ColorType	The specific description of the color represented by the three attributes.	1-1
r	unsignedByte	Defines the red color intensity as a value between 0 and 255.	1-1
g	unsignedByte	Defines the green color intensity as a value between 0 and 255.	1-1
b	unsignedByte	Defines the blue color intensity as a value between 0 and 255.	1-1

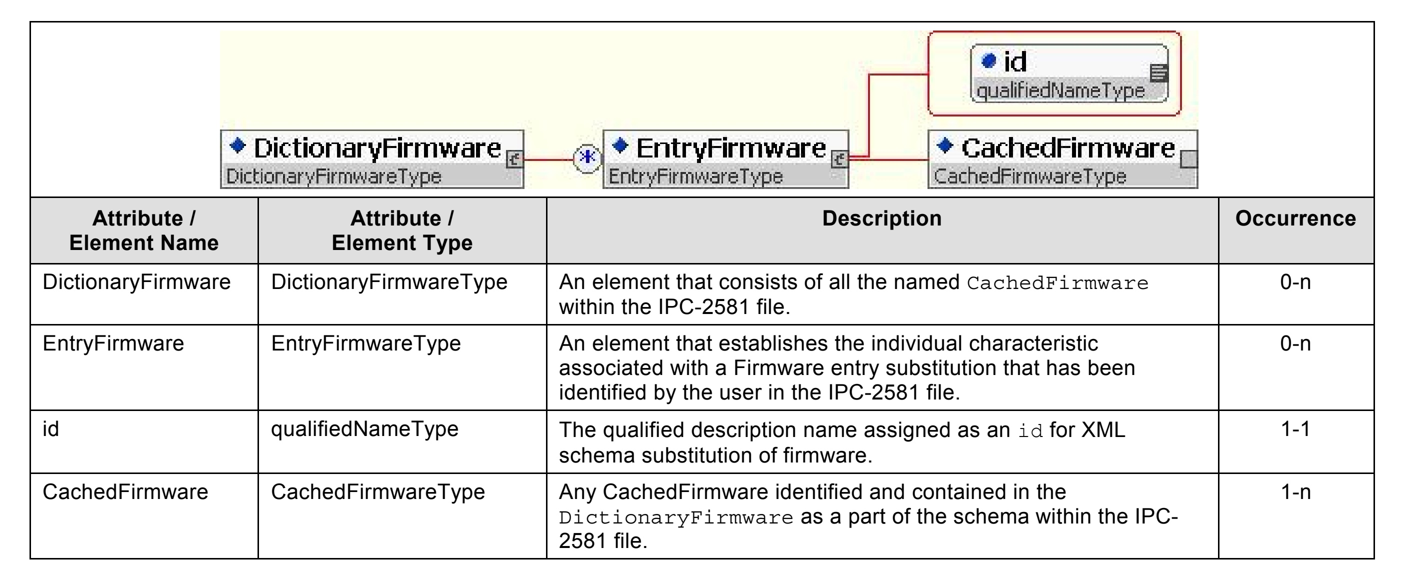
4.11.2 ColorRef

The ColorRef element is used throughout the 2581 file to establish the relationship to a previously defined Color. The ColorRef definition is according to the following characteristics.

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
ColorRef	ColorRefType	The specific reference to a predefined color represented by the three attributes and contained in the DictionaryColor.	1-1
id	qualifiedNameType	The qualified description name assigned as an id standard for XML schema color substitution.	1-1

4.12 Content: DictionaryFirmware

The DictionaryFirmware is intended to provide lookup information on predefined CachedFirmware. The DictionaryFirmware is maintained as part of a substitution group schema. The intent is to have firmware descriptions available that are identified by their characteristics and a specific name (id). They may be reused throughout the file as appropriate. The name (id) of a CachedFirmware must be unique within the DictionaryFirmware.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DictionaryFirmware	DictionaryFirmwareType	An element that consists of all the named CachedFirmware within the IPC-2581 file.	0-n
EntryFirmware	EntryFirmwareType	An element that establishes the individual characteristic associated with a Firmware entry substitution that has been identified by the user in the IPC-2581 file.	0-n
id	qualifiedNameType	The qualified description name assigned as an id for XML schema substitution of firmware.	1-1
CachedFirmware	CachedFirmwareType	Any CachedFirmware identified and contained in the DictionaryFirmware as a part of the schema within the IPC-2581 file.	1-n

The organization of the DictionaryFirmware is accomplished in accordance with the substitution group description criteria. The CachedFirmware description may be any hexEncodedBinary string according to the specific characteristics identified in the following paragraphs. The FirmwareRef function is used in the body of the IPC-2581 file when a specific CachedFirmware has been predefined, assigned a name, and the unique “id” is referenced in the file. This feature permits the use of either a predefined CachedFirmware, or defining the details of the Firmware associated with a particular Component identified by reference designator in the Step section within the file. The description in the file must contain all the features of a particular Firmware under the rules of the particular encoded definition.

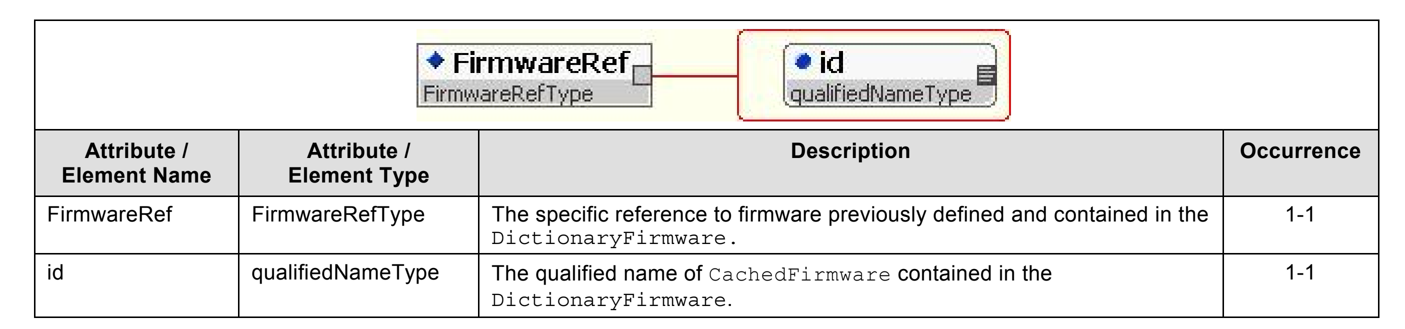
4.12.1 CachedFirmware

The CachedFirmware element is used to describe firmware that will be contained in the DictionaryFirmware. The details are in accordance to the following characteristics.

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
CachedFirmware	CashedFirmwareType	The firmware description needed by a particular component that becomes part of the predefined firmware in the `DictionaryFirmware`.	1-1
hexEncodedBinary	string	An attribute defining the binary code that **shall** be added to a particular component and which is contained in the `DictionaryFirmware`.	1-1

4.12.2 FirmwareRef

The `FirmwareRef` element is used throughout the 2581 file to establish the relationship to a previously defined `CashedFirmware`. The `FirmwareRef` definition is according to the following characteristics.



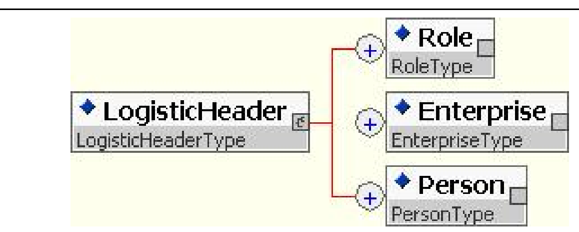
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FirmwareRef	FirmwareRefType	The specific reference to firmware previously defined and contained in the `DictionaryFirmware`.	1-1
id	qualifiedNameType	The qualified name of `CachedFirmware` contained in the `DictionaryFirmware`.	1-1

5 LOGISTIC HEADER

The `LogisticHeader` element consists of information about the owner of the IPC-2581 file. It can be used for configuration management or contact information. The enterprise is also linked to the Bill of Material and the Approved Vendor List.

5.1 LogisticHeader

The `LogisticHeader` describes information pertaining to ordering and delivery. This includes the role played by the individual providing ordering and delivery information, the title of the person responsible and the address and particulars of the enterprise.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LogisticHeader	LogisticHeaderType	The `LogisticHeader` describes information pertaining to ordering and delivery.	1-1
Role	RoleType	Defines the type of activity within the enterprise.	1-n
Enterprise	EnterpriseType	Provides information about the company identified in the BOM or Avl schema.	1-n
Person	PersonType	Identifies the person involved in sending receiving or having anything to do in the trading partner relationship.	1-n

```
<LogisticHeader>
   <Role name = "OWNER" description = "IPC Staff" publicKey = "x6d8rf7xd90mJHR13" authority = "25XX standard development"/>
   <Enterprise id = "IPC" name = "IPC Incorporated - Association Connecting Electronincs Industries" code = "57834" codeType = "CAGE"
            address1 = "2215 Sanders Road" city = "Northbrook" stateProvince = "Illinois" country = "US" postalCode = "60062" phone =
            "+1-847-790-5339" fax = "+1-847-509-9798" email = "Dieterbergman@ipc.org" url = "www.ipc.org"/>
   <Person name = "Dieter W. Bergman" enterpriseRef = "IPC" title = "Director Technology Transfer" email = "Bergdi@ipc.org" phone =
            "847-790-5339" fax = "847-509-9798" mailstop = "2nd Floor " roleRef = "Owner"/>
</LogisticHeader>
```

5.2 Role

A `Role` element declares a type of activity within an `Enterprise`. The attribute values of the `Role` based on the requirements of the activities performed by the role.

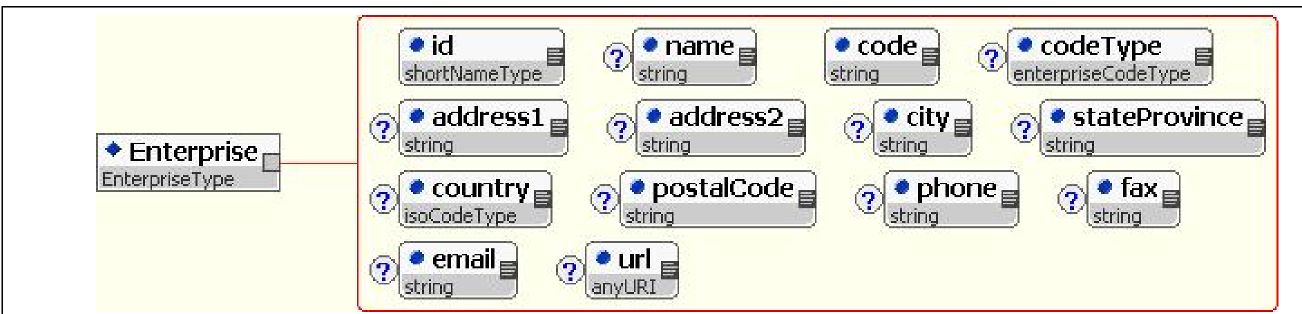
Role RoleType — name string — description roleDescType — publicKey base64Binary — authority string

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Role	RoleType	Defines the type of activity within the enterprise.	1-n
name	string	The `name` attribute defines a globally unique identification of the role within an enterprise The description uniquely identifies a role type used by the enterprise. The name is a `roleType` (a restricted xsd:string) that must be unique within the global (top-level) namespace of the IPC-2581 file. The standard IPC role types are defined as follows: SENDER: Identifies the person sending out the IPC-2581 file. OWNER: Identifies the person who maintains the configuration management of the IPC-2581 file and has the right to increment the file history number of the IPC-2581 file. RECEIVER: Identifies the person receiving the IPC-2581 file. DESIGNER: Identifies the designer of the product described in the IPC-2581 file. ENGINEER: Identifies the engineer who is responsible for the product described in the IPC-2581 file. BUYER: Identifies the person who is responsible for payment. CUSTOMERSERVICE: Identifies the customer service representative who is responsible for the account. DELIVERTO: Identifies the person in the receiving department who takes possession of the shipment in the name of the enterprise. BILLTO: Identifies the person in the billing or purchasing department to whom the billing should be addressed. OTHER: Any other name however completing the description attribute is recommended	1-1
description	string	The `description` attribute defines a role within an enterprise. (The `description` is optional if the IPC definition is to be used.)	0-1
publicKey	base64Binary	The `publicKey` attribute of a role holds the public encryption key if one exists for the role. The key is base64 encoded. (See IETF *RFC 1421* for the base64 algorithm) If a role `publicKey` is present it can be used instead of a `Person`/`publicKey` to encrypt data. The role's `publicKey` is used to encrypt data so only that someone with access to the role's private key can access the data.	0-1
authority	string	The access level associated with this role as defined by the system referenced by `externalConfigurationControlEntryPoint`	0-1

```
<LogisticHeader>
    <Role name = "CircuitDesign" description = "ENGINEER"/>
    <Role name = "LayoutPerson" description = "ENGINEER"/>
    <Role name = "PurchasingNo1" description = "BUYER"/>
    <Role name = "LayoutEngineer" description = "DESIGNER"/>
</LogisticHeader>
```

5.3 Enterprise

The Enterprise element provides information about an enterprise that will be referenced within the IPC-2581 file. The attributes of the Enterprise element are defined as follows:

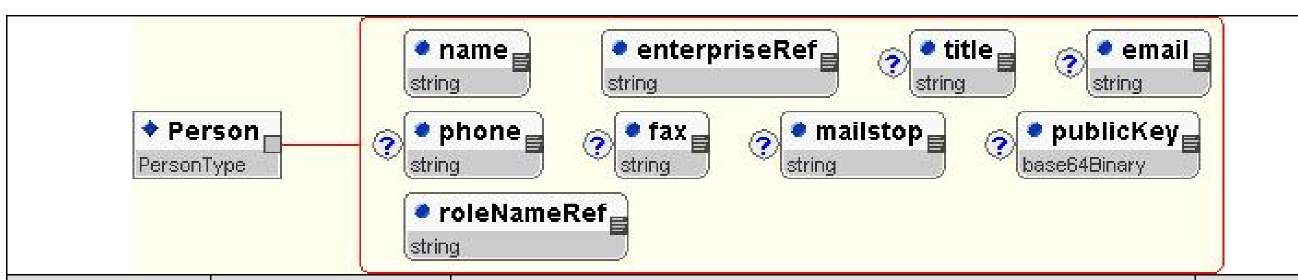


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Enterprise	EnterpriseType	Provides information about the company identified in the Bom or Avl schema.	1-n
id	shortNameType	The id uniquely identifies an enterprise throughout the IPC-2581 file. The id is a shortName data type (a restricted xsd: string) that must be unique within the global (top-level) namespace of the IPC-2581 file. (Suggest "XYZ", "ACME"…).	1-1
name	string	The full name of the enterprise.	0-1
code	string	Value of a CAGE or DUNS code. If no CAGE or DUNS code is available use "NONE" as the value of the code attribute.	1-1
codeType	enterpriseCodeType	One of DUNS or CAGE. The default is DUNS. If the DUNS codeType is selected, then the code attribute of Enterprise is the D-U-N-S Number of the enterprise. (See the reference to D&B D-U-N-S Number at http://www.dnb.com/) If the CAGE codeType is used then the CAGE code of the Enterprise is in the code attribute of Enterprise. (see http://www.dscc.dla.mil/offices/sourcedev/cage.html).	0-1
address1	string	The street address of the Enterprise.	0-1
address2	string	Additional address information for the Enterprise.	0-1
city	string	The city.	0-1
stateProvince	string	The state or province.	0-1
country	isoCodeType	The two-letter ISO country code from the ISO 3166 standard. (See ftp://info.ripe.net/iso3166-countrycodes). The default country is "US."	0-1
postalCode	string	The postal code.	0-1
phone	string	The general phone number for the Enterprise.	0-1
fax	string	The phone number of the Enterprise fax machine.	0-1
email	string	The email address for the Enterprise.	0-1
url	anyURI	The Internet HTTP Web address of the Enterprise.	0-1

```
<LogisticHeader>
    <Role name = "ENGINEER" description = "responsible for data in file"/>
    <Enterprise id = "Acme" name = "Acme Tool and Die Company Inc." code = "1433" codeType = "DUNNS" address1 = "7347 Concorde Ave." address2 = "suite 42" city = "Camden" stateProvince = "NJ" country = "US" postalCode = "08780" phone = "609-458-5943" fax = "609-458-5900" email = "AcmeCorp@mindspring.com" url = "www.Acmeproducts.com"/>
    <Enterprise Id = "Masters" name = "Master Spring Manufacturer" code = "NONE" address1 = "3793 Varembe Ave." address2 = "Room 412" city = "Geneva" stateProvince = "Switzerland" country = "CH" phone = "+ 49-22-47 64 84" email = "masters@swisscom.ch"/>
</LogisticHeader>
```

5.4 Person

The Person element provides information about a person who will be referenced within the IPC-2581 file. The attributes of a Person element are defined as follows:



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Person	PersonType	Identifies the person involved in sending receiving or having anything to do in the trading partner relationship.	1-n
name	string	A string that uniquely identifies the person throughout the IPC-2581 file. The Name must be unique within the global (top-level) namespace of the IPC-2581 file. It may be the full legal name or a known abbreviation.	1-1
enterpriseRef	string	The shortName of the person's company or enterprise. If no enterprise exists, the term "SELF" should be used.	1-1
title	string	The job title of the person.	0-1
email	string	The email address of the person.	0-1
phone	string	The phone number of the person.	0-1
fax	string	The fax machine phone number of the person.	0-1
mailstop	string	The mail stop within the Enterprise, however this may be an alternate address from the Enterprise should the mail e directed somewhere else. In that event, the Enterprise shall be named, but contain no address or contact information.	0-1
publicKey	base64Binary	The publicKey attribute of a person holds the public encryption key if one exists for the person. The key is base64 encoded. (see IETF RFC 1421 for the base64 algorithm) The person's publicKey is used to encrypt data so only that person can access the data.	0-1
roleRef	string	A reference to a globally unique name that identifies the specific role responsibility associated with the general role descriptions.	1-1

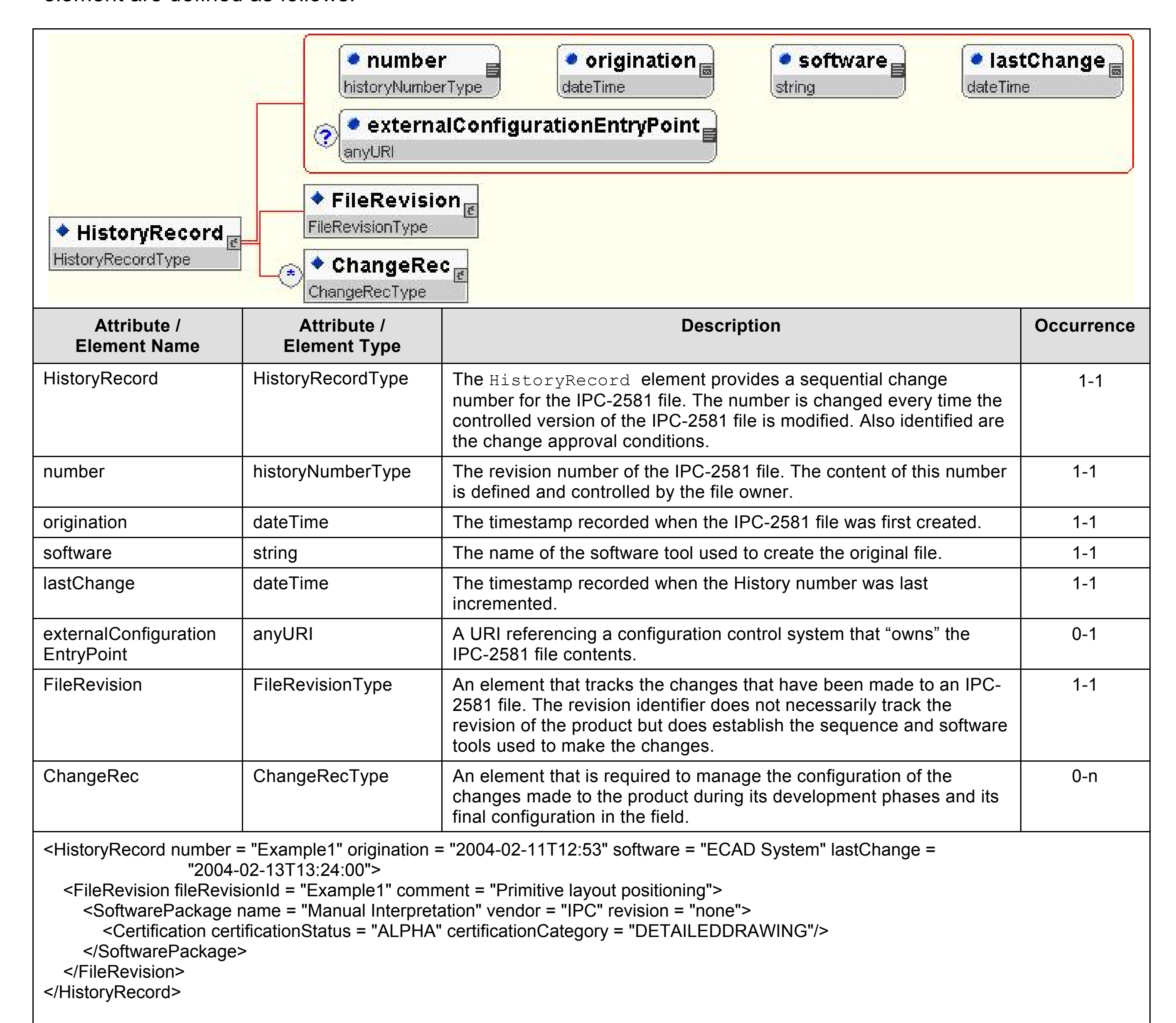
<LogisticHeader>
<Person name = “Dilbert” enterpriseRef = “Acme” email = jdilbert@acme.com phone = “(301) 555-1212”/>
<Person name = “John Jones” enterpriseRef = “Philco Corp” title = “Consultant” email = jones@aol.com phone = “(301) 555-1212” mailstop = “37 Stringer Rd., Overland, OH, 56432” roleRef = JJ Engineer” />
</LogisticHeader>

6 HISTORY RECORD

The History Record element consists of changes performed on the file throughout its history. Several attributes are defined as part of the `History` as well as two elements. These are file revision and change records elements.

6.1 HistoryRecord

The `HistoryRecord` element provides a sequential change number for the IPC-2581 file. The number is changed every time the controlled version of the IPC-2581 file is modified. Only the file owner is allowed to change the value of `HistoryRecord/number`. The attributes of a `HistoryRecord` element are defined as follows:

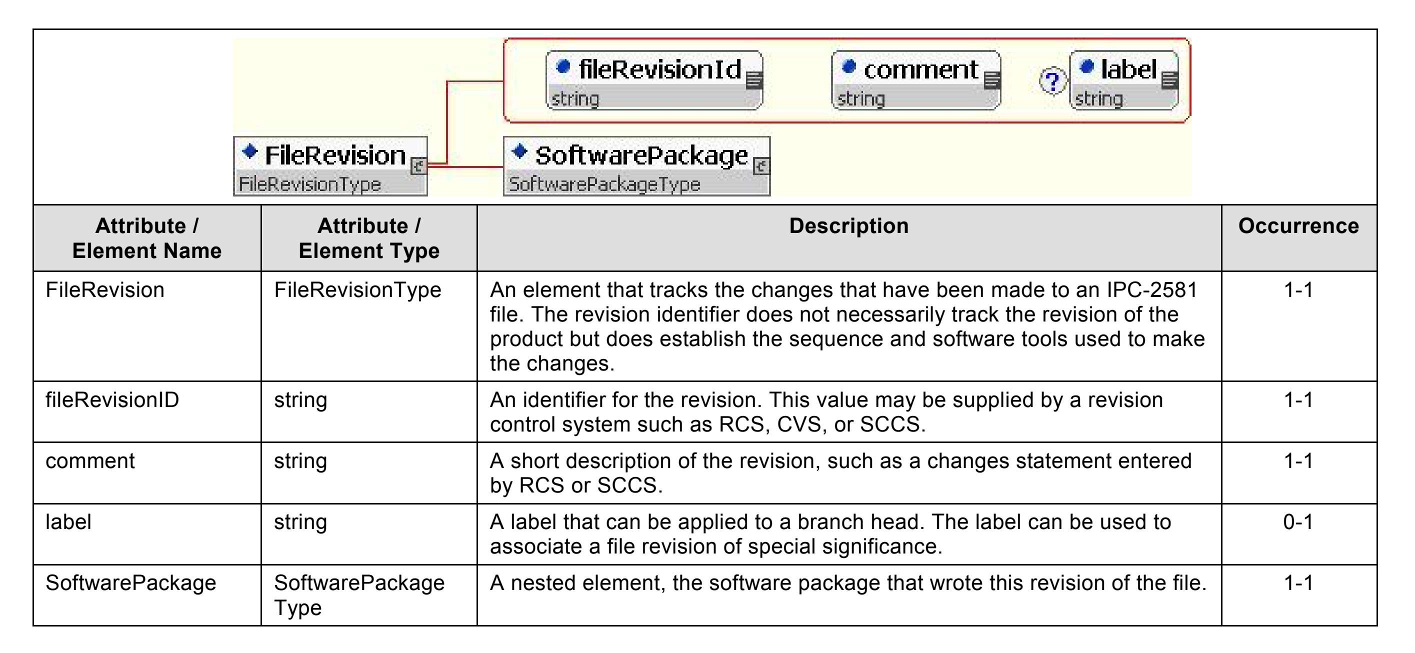


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
HistoryRecord	HistoryRecordType	The `HistoryRecord` element provides a sequential change number for the IPC-2581 file. The number is changed every time the controlled version of the IPC-2581 file is modified. Also identified are the change approval conditions.	1-1
number	historyNumberType	The revision number of the IPC-2581 file. The content of this number is defined and controlled by the file owner.	1-1
origination	dateTime	The timestamp recorded when the IPC-2581 file was first created.	1-1
software	string	The name of the software tool used to create the original file.	1-1
lastChange	dateTime	The timestamp recorded when the History number was last incremented.	1-1
externalConfiguration EntryPoint	anyURI	A URI referencing a configuration control system that “owns” the IPC-2581 file contents.	0-1
FileRevision	FileRevisionType	An element that tracks the changes that have been made to an IPC-2581 file. The revision identifier does not necessarily track the revision of the product but does establish the sequence and software tools used to make the changes.	1-1
ChangeRec	ChangeRecType	An element that is required to manage the configuration of the changes made to the product during its development phases and its final configuration in the field.	0-n

```
<HistoryRecord number = "Example1" origination = "2004-02-11T12:53" software = "ECAD System" lastChange =
                        "2004-02-13T13:24:00">
   <FileRevision fileRevisionId = "Example1" comment = "Primitive layout positioning">
      <SoftwarePackage name = "Manual Interpretation" vendor = "IPC" revision = "none">
         <Certification certificationStatus = "ALPHA" certificationCategory = "DETAILEDDRAWING"/>
      </SoftwarePackage>
   </FileRevision>
</HistoryRecord>
```

6.2 FileRevision

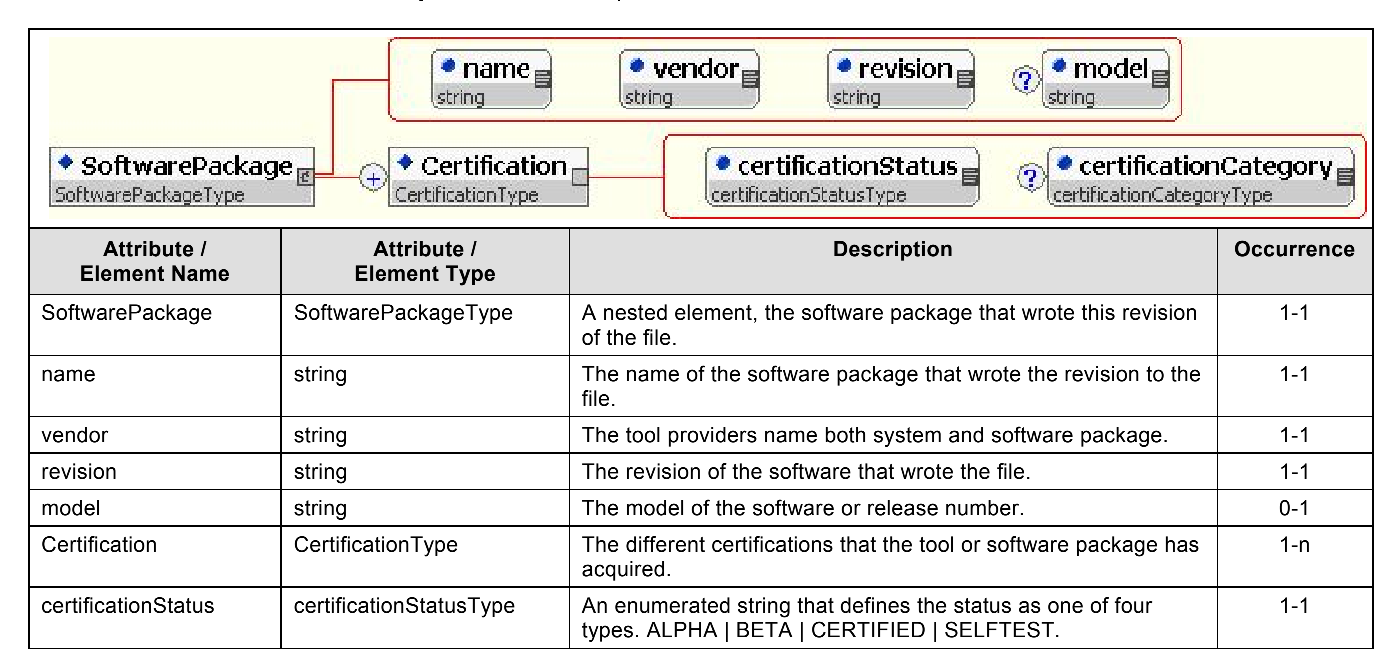
The `FileRevision` element tracks changes to the IPC-2581 file. The revision identifier does not necessarily track the revision of the product. The purpose of the `FileRevision` is to track which software tools were used to make changes to the file and the sequence in which the changes were made.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
FileRevision	FileRevisionType	An element that tracks the changes that have been made to an IPC-2581 file. The revision identifier does not necessarily track the revision of the product but does establish the sequence and software tools used to make the changes.	1-1
fileRevisionID	string	An identifier for the revision. This value may be supplied by a revision control system such as RCS, CVS, or SCCS.	1-1
comment	string	A short description of the revision, such as a changes statement entered by RCS or SCCS.	1-1
label	string	A label that can be applied to a branch head. The label can be used to associate a file revision of special significance.	0-1
SoftwarePackage	SoftwarePackage Type	A nested element, the software package that wrote this revision of the file.	1-1

6.3 SoftwarePackage

The `SoftwarePackage` element is the description of the software package that was used to create the revision to the file. This includes the revision of the software that wrote the file as well as the vendor name and platform model. Also added to the `SoftwarePackage` schema is any certification that has occurred of the software's ability to meet the requirements of the IPC-2581 standard.

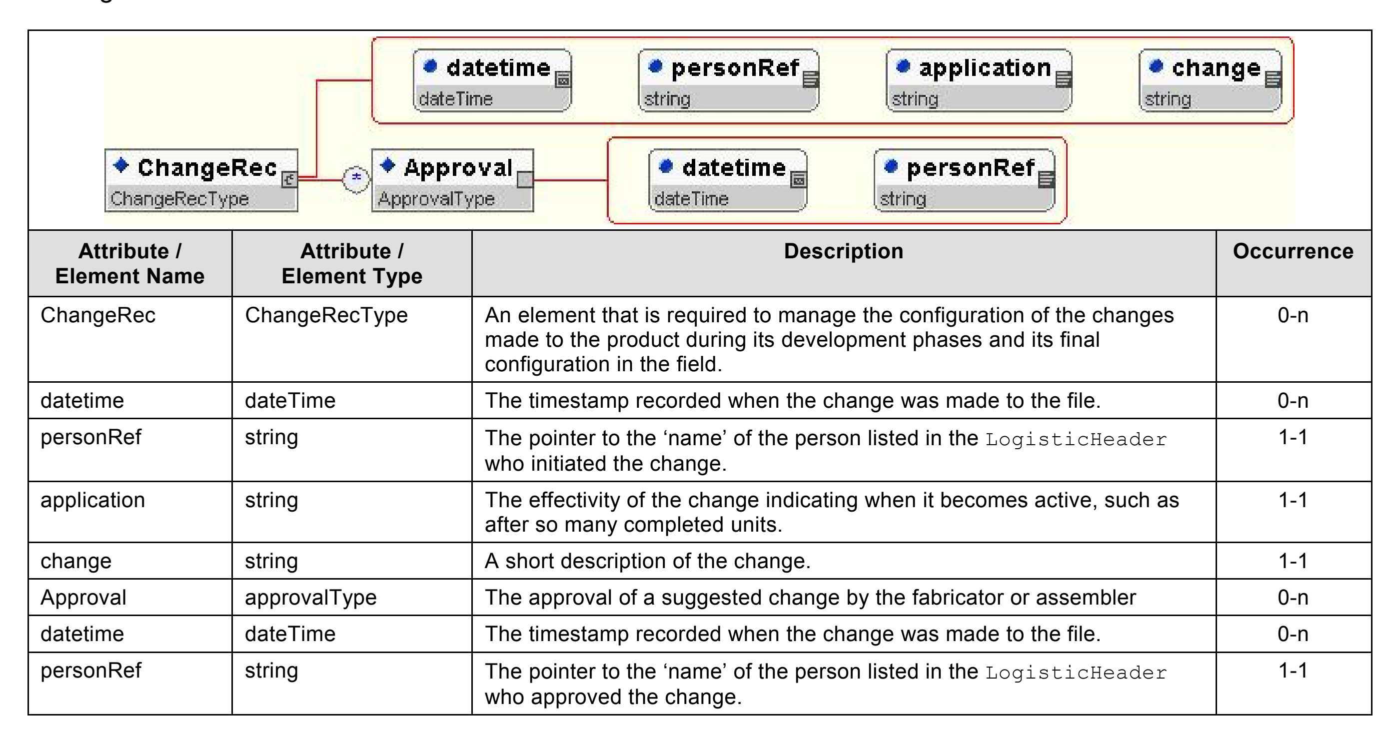


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
SoftwarePackage	SoftwarePackageType	A nested element, the software package that wrote this revision of the file.	1-1
name	string	The name of the software package that wrote the revision to the file.	1-1
vendor	string	The tool providers name both system and software package.	1-1
revision	string	The revision of the software that wrote the file.	1-1
model	string	The model of the software or release number.	0-1
Certification	CertificationType	The different certifications that the tool or software package has acquired.	1-n
certificationStatus	certificationStatusType	An enumerated string that defines the status as one of four types. ALPHA | BETA | CERTIFIED | SELFTEST.	1-1

certificationCategory	certificationCategory Type	The various categories that exist for certification of the type of activities related to building electronic assemblies. An enumerated string consisting of: ASSEMBLYDRAWING | ASSEMBLYFIXTUREGENERATION | ASSEMBLYPANEL | ASSEMBLYPREPTOOLS | ASSEMBLYTESTFIXTUREGENERATION | ASSEMBLYTESTGENERATION | BOARDFABRICATION | BOARDFIXTUREGENERATION | BOARDPANEL | BOARDTESTGENERATION | COMPONENTPLACEMENT | DETAILEDDRAWING | FABRICATIONDRAWING | GENERALASSEMBLY | GLUEDOT | MECHANICALHARDWARE | MULTIBOARDPARTLIST | PHOTOTOOLS | SCHEMATICDRAWINGS | SINGLEBOARDPARTLIST | SOLDERSTENCILPASTE | SPECSOURCECONTROLDRAWING.	0-1

6.4 ChangeRec

The `ChangeRec` element is the information needed for configuration management of the changes made to the product that the data file represents. The characteristics are stored by the `datecode` that the change record was executed. The information can also be used to obtain approval of a suggested change.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
ChangeRec	ChangeRecType	An element that is required to manage the configuration of the changes made to the product during its development phases and its final configuration in the field.	0-n
datetime	dateTime	The timestamp recorded when the change was made to the file.	0-n
personRef	string	The pointer to the 'name' of the person listed in the `LogisticHeader` who initiated the change.	1-1
application	string	The effectivity of the change indicating when it becomes active, such as after so many completed units.	1-1
change	string	A short description of the change.	1-1
Approval	approvalType	The approval of a suggested change by the fabricator or assembler	0-n
datetime	dateTime	The timestamp recorded when the change was made to the file.	0-n
personRef	string	The pointer to the 'name' of the person listed in the `LogisticHeader` who approved the change.	1-1

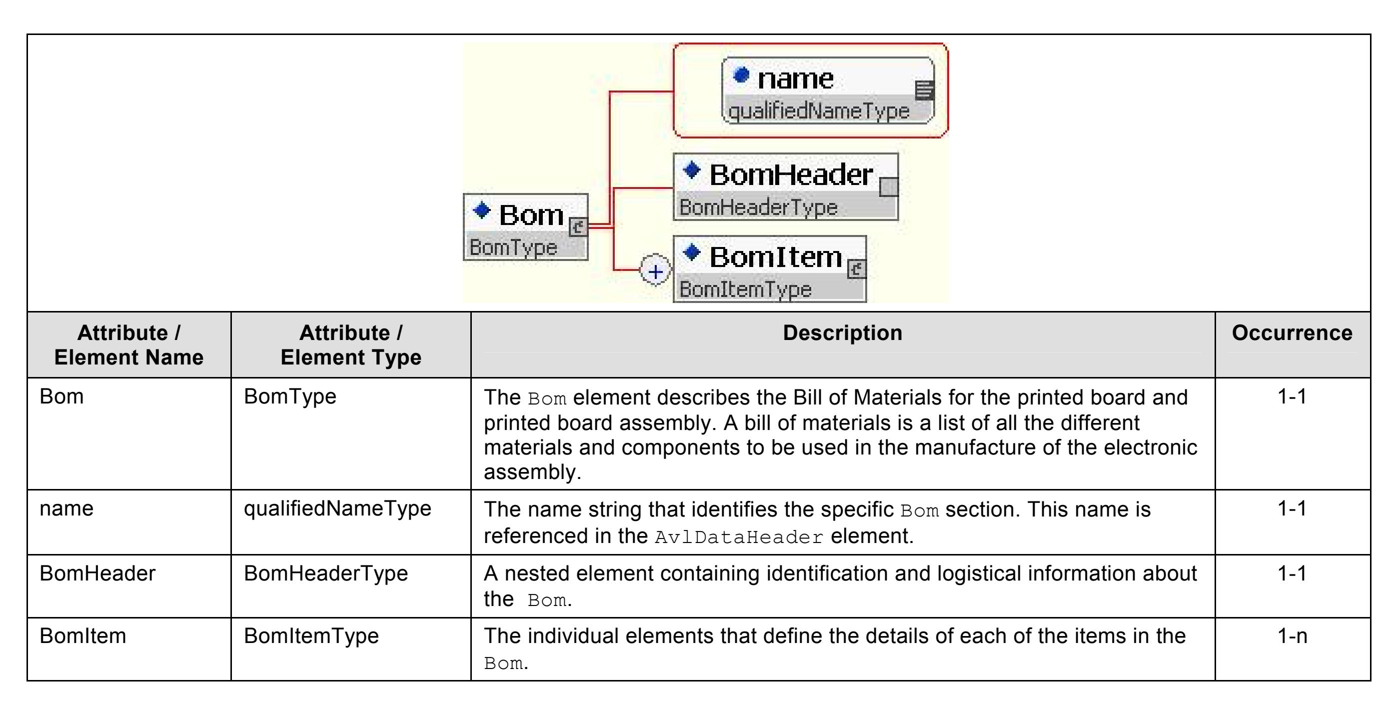
7 BOM (Material List)

This section describes the Bill of Materials for the printed board and printed board assembly. A bill of materials is a list of all the different materials and components to be used in the manufacture of the electronic assembly. The information is arranged by a specific category of material or components and then by the OEM Design Number (ODN). This is the number assigned by the owner of the file. Each ODN has a list of attributes and is accompanied by a list of the various specific uses of the materials or components on the electronic assembly, each with its private name or reference designator.

The BOM dataset represents the list of materials or components found on a particular board, keyed by the OEM Design Number (ODN). The original BOM is delivered by the owner of the file (OEM, EMS, etc.) in the early stages of the design. The Bom element is composed of the BomHeader and the BomData

For example, ODN **348324-001** can be of package **pqfp100**, has an Internal Part Number (IPN) **30020A** and may have four occurrences on the board, labeled **U14**, **U15**, **U75**, **U76**. Each occurrence is called a Reference Designator (RefDes for short).

The IPC-2581 file can contain several BOM elements. Each one has a BomHeader sub-element with board and date/time information. The main data resides in the sub-element BomData.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Bom	BomType	The Bom element describes the Bill of Materials for the printed board and printed board assembly. A bill of materials is a list of all the different materials and components to be used in the manufacture of the electronic assembly.	1-1
name	qualifiedNameType	The name string that identifies the specific Bom section. This name is referenced in the AvlDataHeader element.	1-1
BomHeader	BomHeaderType	A nested element containing identification and logistical information about the Bom.	1-1
BomItem	BomItemType	The individual elements that define the details of each of the items in the Bom.	1-n

```
<Bom name = "TestBoard1">
<BomHeader assembly = "Karens Design" revision = "Prototype" stepListRef = "KarensBoard"/>
    <BomItem OEMDesignNumberRef = "Fabricated" quantity = "1" numberIO = "4" category = "ELECTRICAL"    description = "Card
                Edge Connector">
      <RefDes name = "J1" populate = "FALSE"/>
      <Characteristics category = "ELECTRICAL"/>
    </BomItem>
    <BomItem OEMDesignNumberRef = "Sample1234" quantity = "1" numberIO = "8" category = "ELECTRICAL" internalPartNumber =
                "Molex 354892" description = "Biforcated Thru-hole connector" packageRef = "Connector1">
      <RefDes name = "J2" populate = "TRUE"/>
      <Characteristics category = "ELECTRICAL"/>
    </BomItem>
    <BomItem OEMDesignNumberRef = "SOIC129867" quantity = "1" numberIO = "8" category = "ELECTRICAL" internalPartNumber =
                "Phillips IC2436" description = "SOIC 1.27 pitch" packageRef = "SOIC12">
      <RefDes name = "U1" populate = "TRUE"/>
      <Characteristics category = "ELECTRICAL">
        <Textual definitionSource = "Pretested Logic" textualCharacteristicName = "Per Supplier Data Sheet"/>
      </Characteristics>
    </BomItem>
    <BomItem OEMDesignNumberRef = "CAP 24A1846" quantity = "1" numberIO = "2" category = "ELECTRICAL" internalPartNumber =
      "Phillips Cap1235" description = "3225 Surface Mount Capacitor" packageRef = "Capacitor1">
      <RefDes name = "C1" populate = "TRUE"/>
      <Characteristics category = "ELECTRICAL">
        <Measured measuredCharacteristicName = "Capacitance" measuredCharacteristicValue = "20 Microfarads"
           engineeringUnitOfMeasure = "Microfarads" engineeringNegativeTolerance = "3 microfarads" engineering
          PositiveTolerance = "3 microfarads"/>
```

7.1 BOM Header

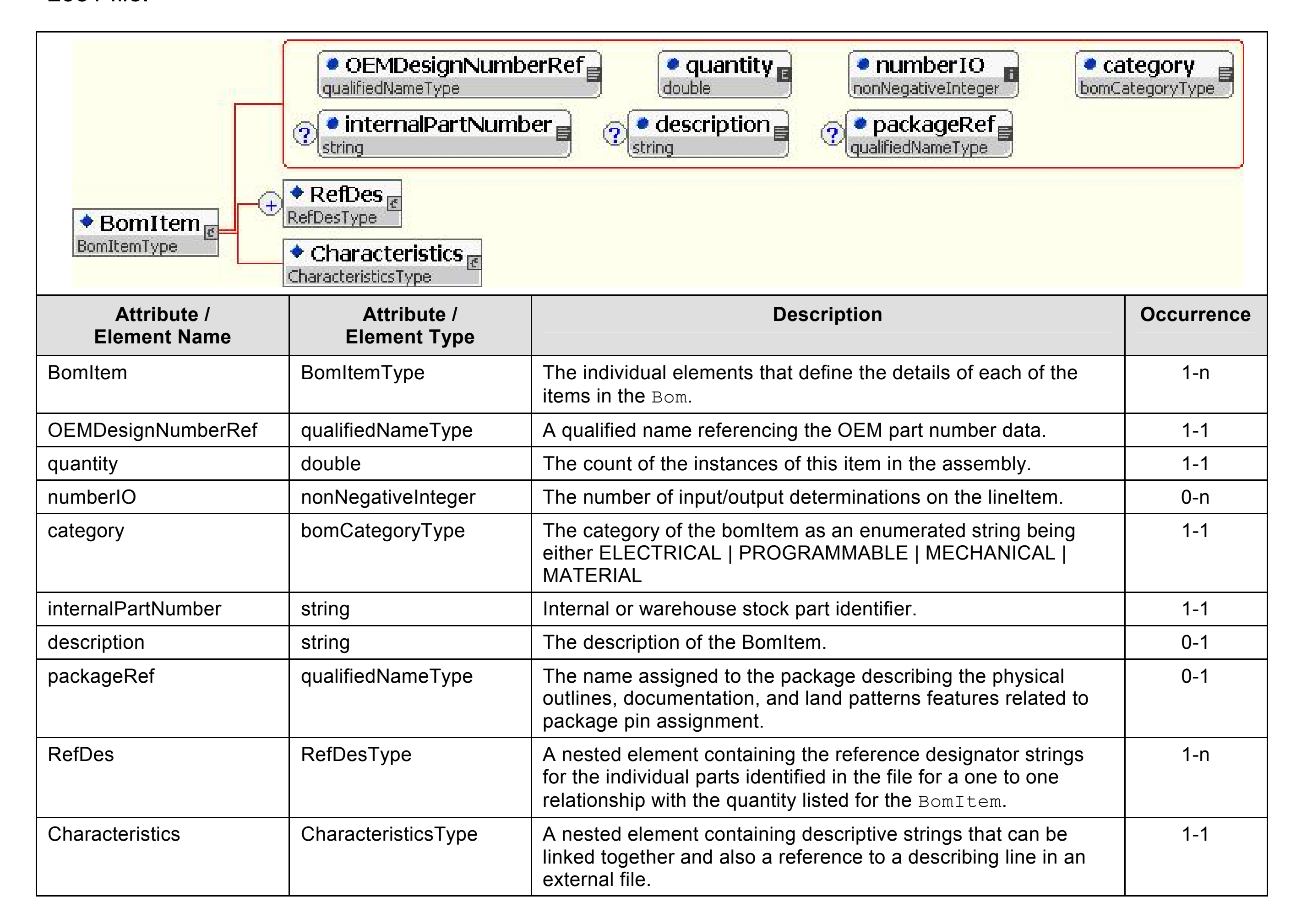
Each `Bom` in the IPC-2581 file has a `BomHeader` element. This is a mandatory requirement as a part of the `Bom` element. The following characteristics are necessary to properly describe a `Bom`.

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
BomHeader	BomHeaderType	A nested element containing identification and logistical information about the `Bom`.	1-1
assembly	qualifiedNameType	Electronic assembly name as parsed from the `Bom` file.	1-1
revision	string	Revision as parsed from the `Bom` file.	1-1
affecting	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). True equals that the current BOM was used in the assembly merge process in the job and therefore was the affecting one. This is due to the fact that there can be multiple BOMs in a job, but only one has been used to affect the current top and bottom component placements sections.	0-1
stepListRef	qualifiedNameType	Identification of specific steps used to help describe the BomItem within the category of materials	1-1

7.2 BomItem

Each `BomItem` is a part of the `BomItem` list. A `BomItem` consists of a variety of attributes. `BomItem` contains the reference to the OEM Design Number (ODN), the line item of the ODN, a quantity of parts required, and optional `internalPartNumber` (IPN), description of the `bomItem` and a reference to the package type (`packageRef`). The `BomItem` also contains three additional elements that include the list of reference designators (`RefDes`) associated with the `BomItem`, a list of detail descriptions related to the `BomItem` (`DescList`), and FirmWare (`Firmware`) associated with programming a part that needs those characteristics. `Multiple RefDes` lists may be maintained since there may be several reference designator file locations.

The attributes are shown in the following table and are a mandatory part of the `Bom` section of the IPC-2581 file.

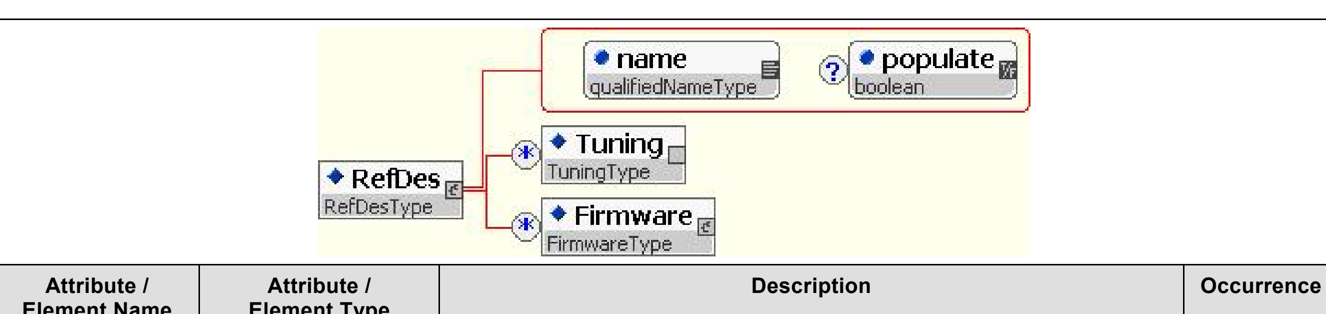


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
BomItem	BomItemType	The individual elements that define the details of each of the items in the `Bom`.	1-n
OEMDesignNumberRef	qualifiedNameType	A qualified name referencing the OEM part number data.	1-1
quantity	double	The count of the instances of this item in the assembly.	1-1
numberIO	nonNegativeInteger	The number of input/output determinations on the lineItem.	0-n
category	bomCategoryType	The category of the bomItem as an enumerated string being either ELECTRICAL | PROGRAMMABLE | MECHANICAL | MATERIAL	1-1
internalPartNumber	string	Internal or warehouse stock part identifier.	1-1
description	string	The description of the BomItem.	0-1
packageRef	qualifiedNameType	The name assigned to the package describing the physical outlines, documentation, and land patterns features related to package pin assignment.	0-1
RefDes	RefDesType	A nested element containing the reference designator strings for the individual parts identified in the file for a one to one relationship with the quantity listed for the `BomItem`.	1-n
Characteristics	CharacteristicsType	A nested element containing descriptive strings that can be linked together and also a reference to a describing line in an external file.	1-1

```
<Bom name = "TestBoard1">
    <BomHeader assembly = "Karens Design" revision = "Prototype" stepListRef = "KarensBoard"/>
     <BomItem OEMDesignNumberRef = "Fabricated" quantity = "1" numberIO = "4" category = "ELECTRICAL"  description = "Card Edge
            Connector">
        <RefDes name = "J1" populate = "FALSE"/>
        <Characteristics category = "ELECTRICAL"/>
     </BomItem>
     <BomItem OEMDesignNumberRef = "Sample1234" quantity = "1" numberIO = "8" category = "ELECTRICAL"    internalPartNumber =
            "Molex 354892" description = "Biforcated Thru-hole connector" packageRef = "Connector1">
        <RefDes name = "J2" populate = "TRUE"/>
        <Characteristics category = "ELECTRICAL"/>
     </BomItem>
     <BomItem OEMDesignNumberRef = "SOIC129867" quantity = "1" numberIO = "8" category = "ELECTRICAL" internalPartNumber =
            "Phillips IC2436" description = "SOIC 1.27 pitch" packageRef = "SOIC12">
        <RefDes name = "U1" populate = "TRUE"/>
        <Characteristics category = "ELECTRICAL">
           <Textual definitionSource = "Pretested Logic" textualCharacteristicName = "Per Supplier Data Sheet"/>
        </Characteristics>
     </BomItem>
     <BomItem OEMDesignNumberRef = "CAP 24A1846" quantity = "1" numberIO = "2" category = "ELECTRICAL" internalPartNumber =
            "Phillips Cap1235" description = "3225 Surface Mount Capacitor" packageRef = "Capacitor1">
        <RefDes name = "C1" populate = "TRUE"/>
        <Characteristics category = "ELECTRICAL">
           <Measured measuredCharacteristicName = "Capacitance" measuredCharacteristicValue = "20    Microfarads"
                 engineeringUnitOfMeasure = "Microfarads" engineeringNegativeTolerance = "3 microfarads"
              engineeringPositiveTolerance = "3 microfarads"/>
        </Characteristics>
     </BomItem>
```


7.2.1 RefDes

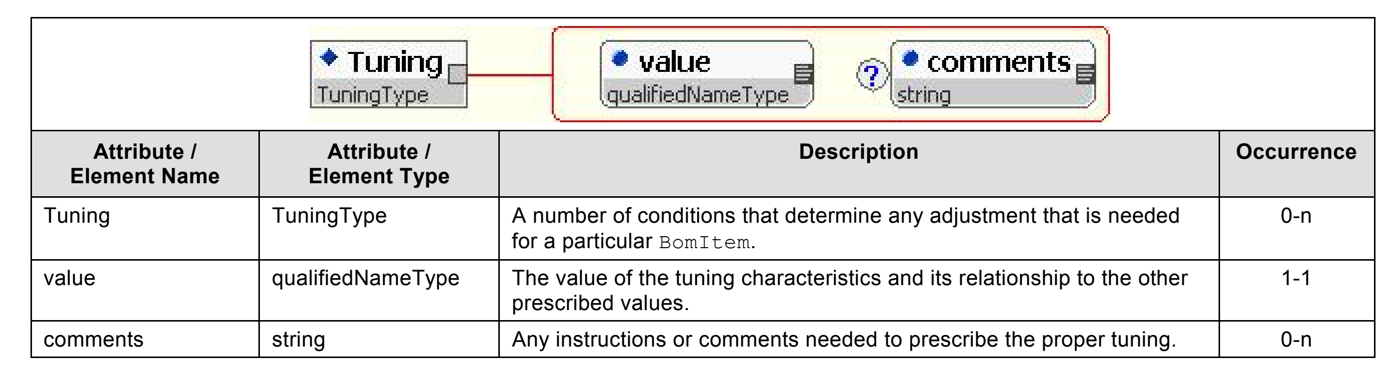
The `RefDes` is an element that represents the specific reference designator associated with a component that becomes a part of the electronic assembly. This is a mandatory requirement for all `BomItems` that have a reference designator associated with their ELECTRICAL descriptions. In this instance the standard set of reference designator letters **shall** be used. i.e., R = Resistor, C = Capacitor, CR = Diode etc. The prefix letter M **shall** be used for all MECHANICAL parts, P **shall** be used for all Process MATERIAL `bomItems`, and S for all Software PROGRAMMABLE `bomItems`.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
RefDes	RefDesType	A nested element containing the reference designator strings for the individual parts identified in the file for a one to one relationship with the quantity listed for the `BomItem`.	0-1
name	qualifiedNameType	The qualifiedNameType that identifies the reference designator used as the attribute `refDes` of the `Component` element in `Step`.	1-1
populate	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). True equals that the `RefDes` was populated; False indicates that it was not. TRUE is the default.	0-1
Tuning	TuningType	A number of conditions that determine any adjustment that is needed for a particular `BomItem`.	0-n
Firmware	FirmwareType	A nested element containing descriptive strings that can be linked together to describe the software implementation for an individual `BomItem.`	0-n

7.2.1.1 Tuning

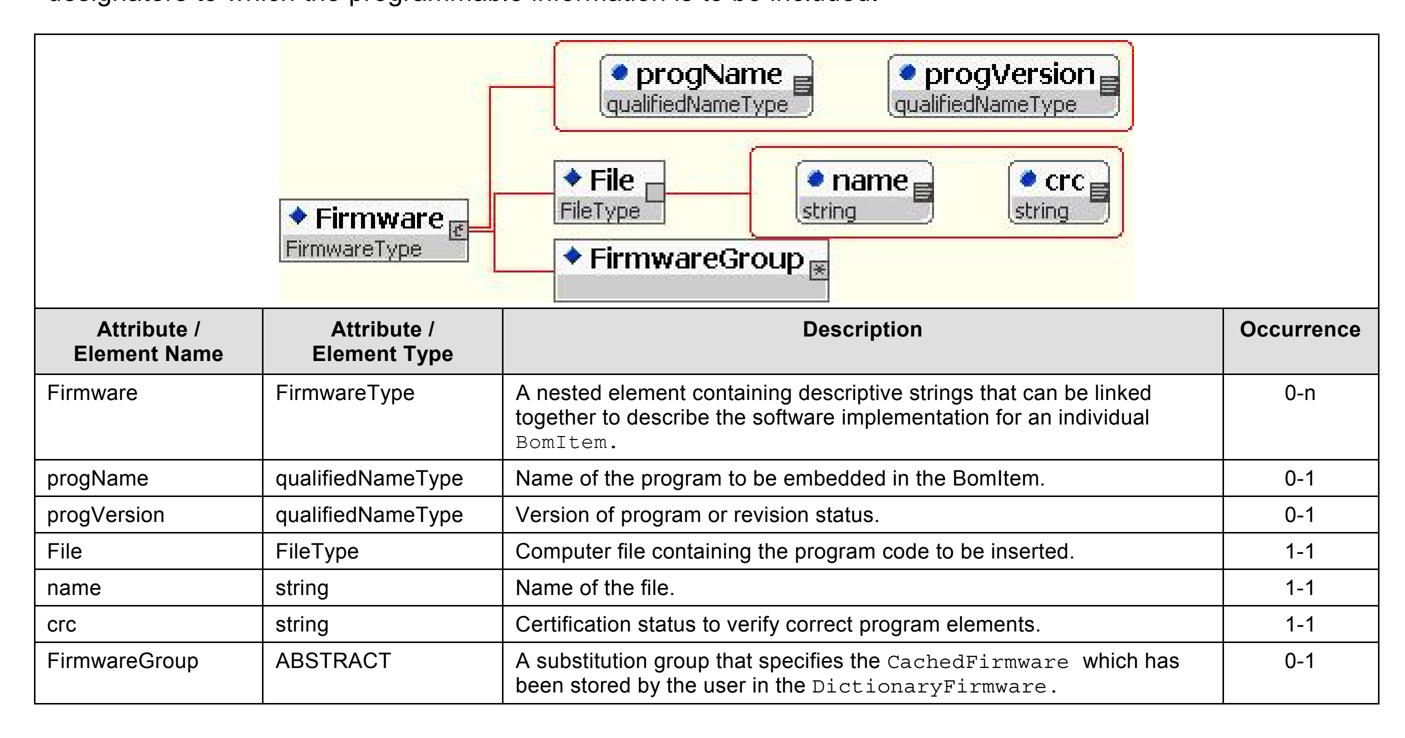
The `Tuning` element represents conditions that determine any adjustment that is needed for a particular `BomItem`.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Tuning	TuningType	A number of conditions that determine any adjustment that is needed for a particular `BomItem`.	0-n
value	qualifiedNameType	The value of the tuning characteristics and its relationship to the other prescribed values.	1-1
comments	string	Any instructions or comments needed to prescribe the proper tuning.	0-n

7.2.1.2 Firmware

A nested element containing descriptive strings that can be linked together to describe the software implementation for an individual `BomItem` and associates the characteristics of the specific reference designators to which the programmable information is to be included.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Firmware	FirmwareType	A nested element containing descriptive strings that can be linked together to describe the software implementation for an individual `BomItem`.	0-n
progName	qualifiedNameType	Name of the program to be embedded in the BomItem.	0-1
progVersion	qualifiedNameType	Version of program or revision status.	0-1
File	FileType	Computer file containing the program code to be inserted.	1-1
name	string	Name of the file.	1-1
crc	string	Certification status to verify correct program elements.	1-1
FirmwareGroup	ABSTRACT	A substitution group that specifies the `CachedFirmware` which has been stored by the user in the `DictionaryFirmware`.	0-1

7.2.2 Characteristics

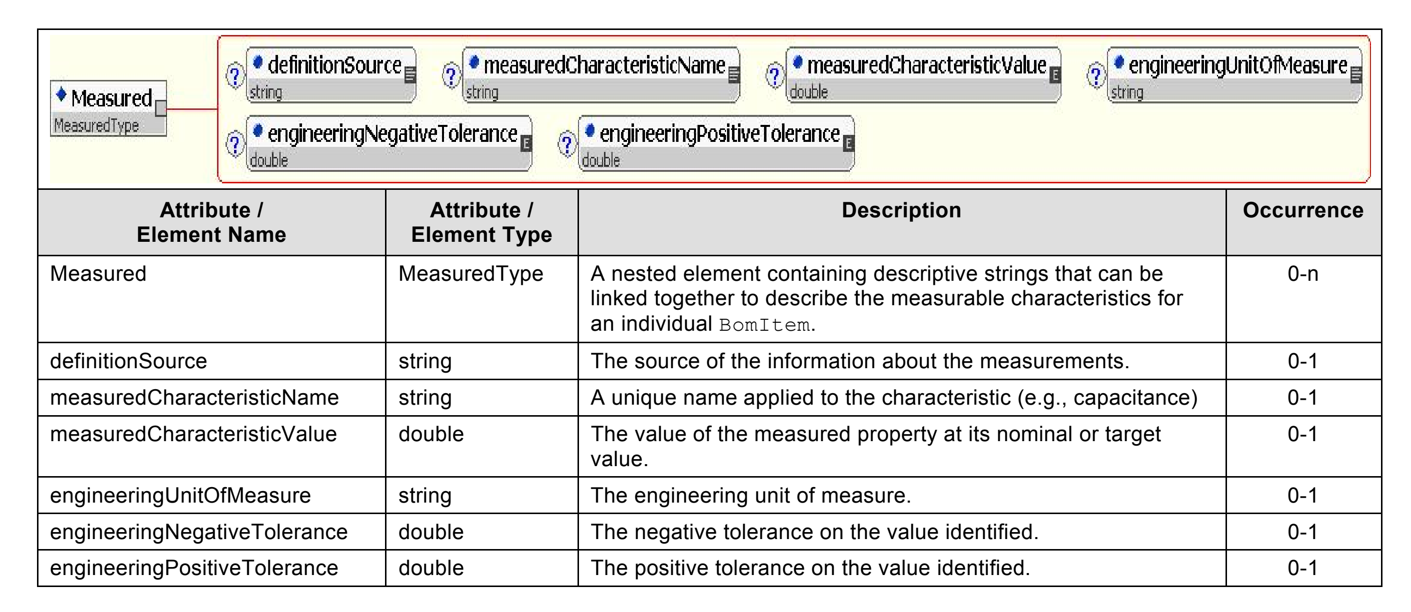
A group of specific characteristics applicable to a particular `BomItem`; they all relate to one of the categories to which the `BomItem` belongs. Each characteristic has its own level of requirements and are defined under the major element `Characteristics`.

category
bomCategoryType
Measured
MeasuredType
Ranged
RangedType
Characteristics
CharacteristicsType
Enumerated
EnumeratedType
Textual
TextualType

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Characteristics	CharacteristicsType	A nested element containing descriptive strings that can be linked together and also a reference to a describing line in an external file.	1-1
category	bomCategoryType	Defines the type of material or component category to which the `BomItem` belongs.	1-1
Measured	MeasuredType	A nested element containing descriptive strings that can be linked together to describe the measurable characteristics for an individual `BomItem`.	0-n
Ranged	RangedType	A nested element containing descriptive strings that can be linked together to describe the tolerances or ranges of variation that can be applied to the characteristics for an individual `BomItem`.	0-n
Enumerated	EnumeratedType	A nested element containing descriptive strings that can be linked together to describe those values that define the numerical characteristics and the source for that information for an individual `BomItem`.	0-n
Textual	TextualType	A nested element containing descriptive strings that can be linked together to describe any textual characteristics and their source for an individual `BomItem`.	0-n

7.2.2.1 Measured

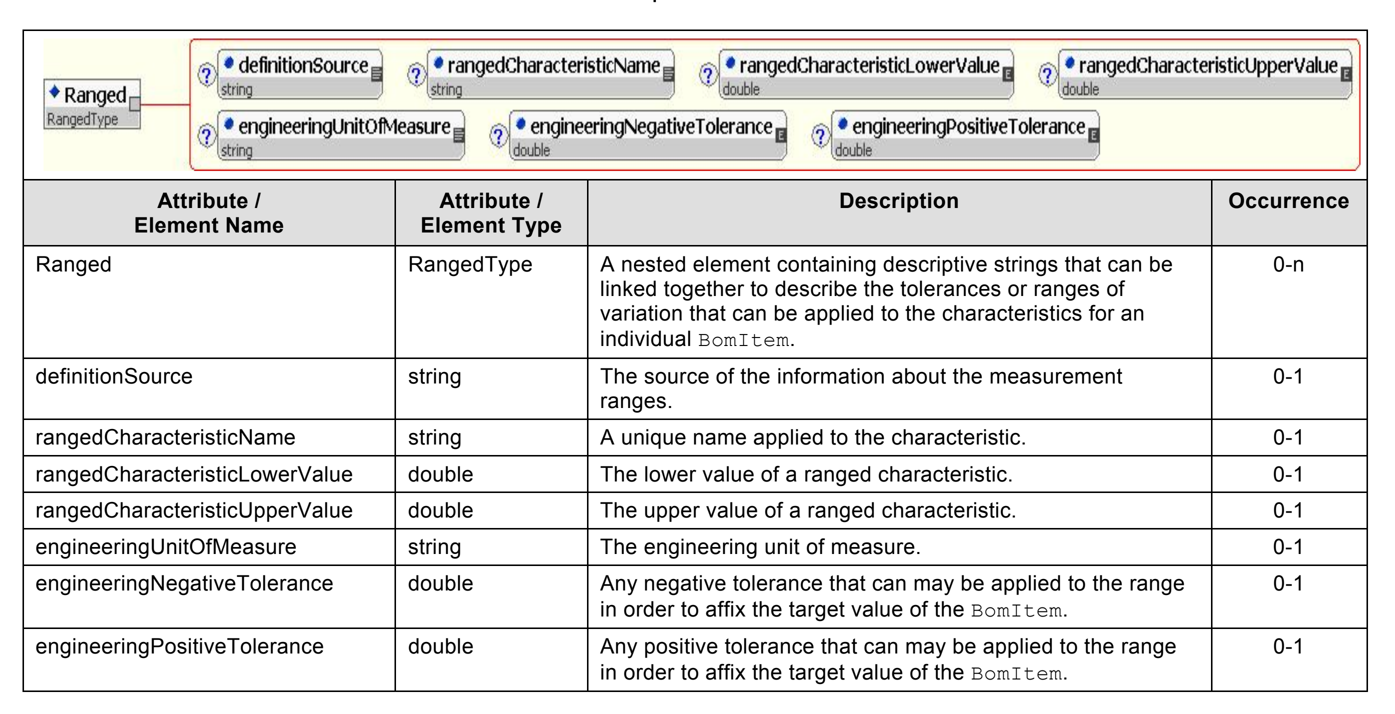
The `Measured` elements are those properties that when linked together describe the measurable characteristics for an individual `BomItem`. These characteristics provide the nominal value and also include the tolerances on the measurement.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Measured	MeasuredType	A nested element containing descriptive strings that can be linked together to describe the measurable characteristics for an individual `BomItem`.	0-n
definitionSource	string	The source of the information about the measurements.	0-1
measuredCharacteristicName	string	A unique name applied to the characteristic (e.g., capacitance)	0-1
measuredCharacteristicValue	double	The value of the measured property at its nominal or target value.	0-1
engineeringUnitOfMeasure	string	The engineering unit of measure.	0-1
engineeringNegativeTolerance	double	The negative tolerance on the value identified.	0-1
engineeringPositiveTolerance	double	The positive tolerance on the value identified.	0-1

7.2.2.2 Ranged

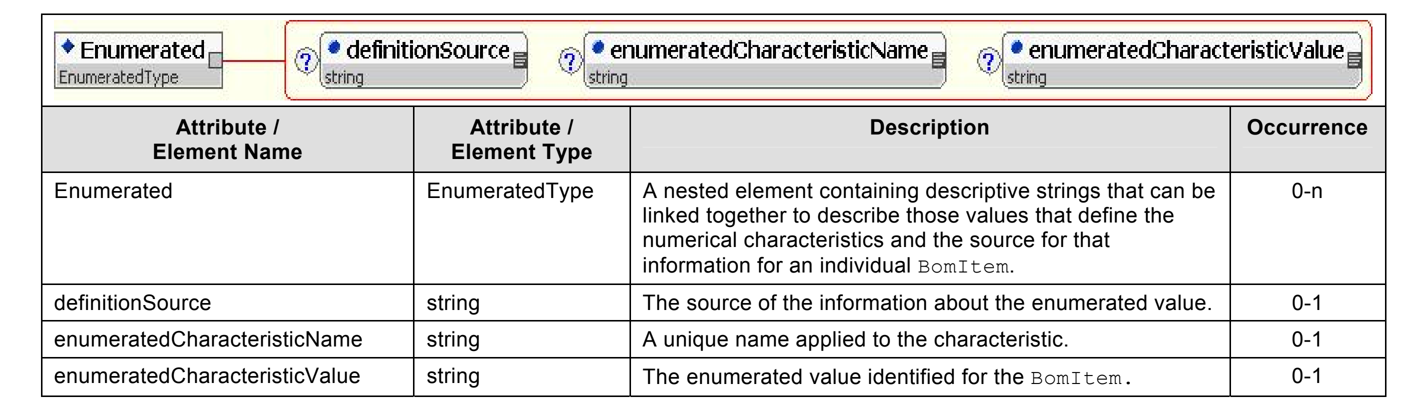
The `Ranged` elements are those properties that when linked together describe the ranges that a `BomItem` must meet. These range characteristics include the upper and lower limit of the range as well as the tolerances on the measurement. These values are compared against those that have been measured to ascertain that the `BomItem` is within specifications.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Ranged	RangedType	A nested element containing descriptive strings that can be linked together to describe the tolerances or ranges of variation that can be applied to the characteristics for an individual `BomItem`.	0-n
definitionSource	string	The source of the information about the measurement ranges.	0-1
rangedCharacteristicName	string	A unique name applied to the characteristic.	0-1
rangedCharacteristicLowerValue	double	The lower value of a ranged characteristic.	0-1
rangedCharacteristicUpperValue	double	The upper value of a ranged characteristic.	0-1
engineeringUnitOfMeasure	string	The engineering unit of measure.	0-1
engineeringNegativeTolerance	double	Any negative tolerance that can may be applied to the range in order to affix the target value of the `BomItem`.	0-1
engineeringPositiveTolerance	double	Any positive tolerance that can may be applied to the range in order to affix the target value of the `BomItem`.	0-1

7.2.2.3 Enumerated

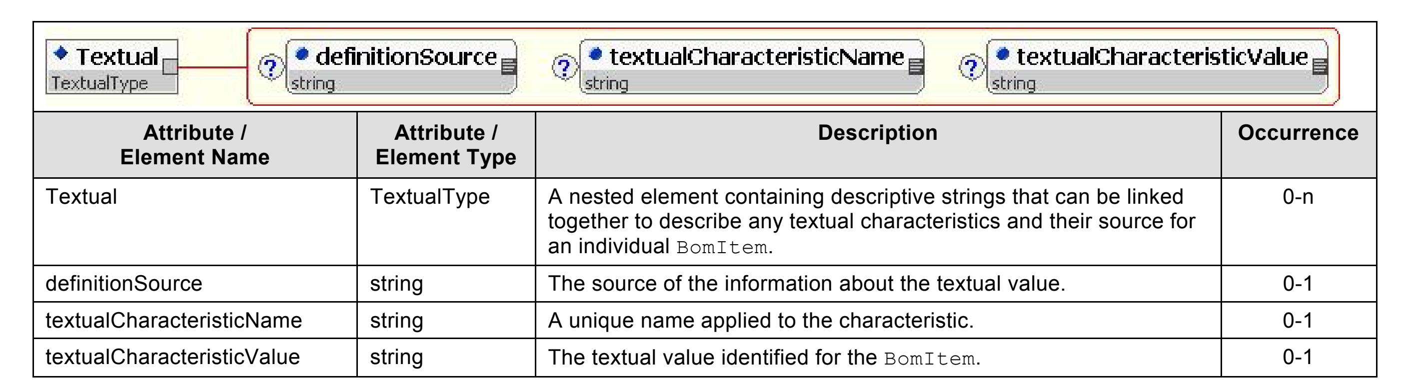
The `Enumerated` elements are those properties that, when linked together, describe the enumerated value of a `BomItem` as well as the source of that information.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Enumerated	EnumeratedType	A nested element containing descriptive strings that can be linked together to describe those values that define the numerical characteristics and the source for that information for an individual `BomItem`.	0-n
definitionSource	string	The source of the information about the enumerated value.	0-1
enumeratedCharacteristicName	string	A unique name applied to the characteristic.	0-1
enumeratedCharacteristicValue	string	The enumerated value identified for the `BomItem`.	0-1

7.2.2.4 Textual

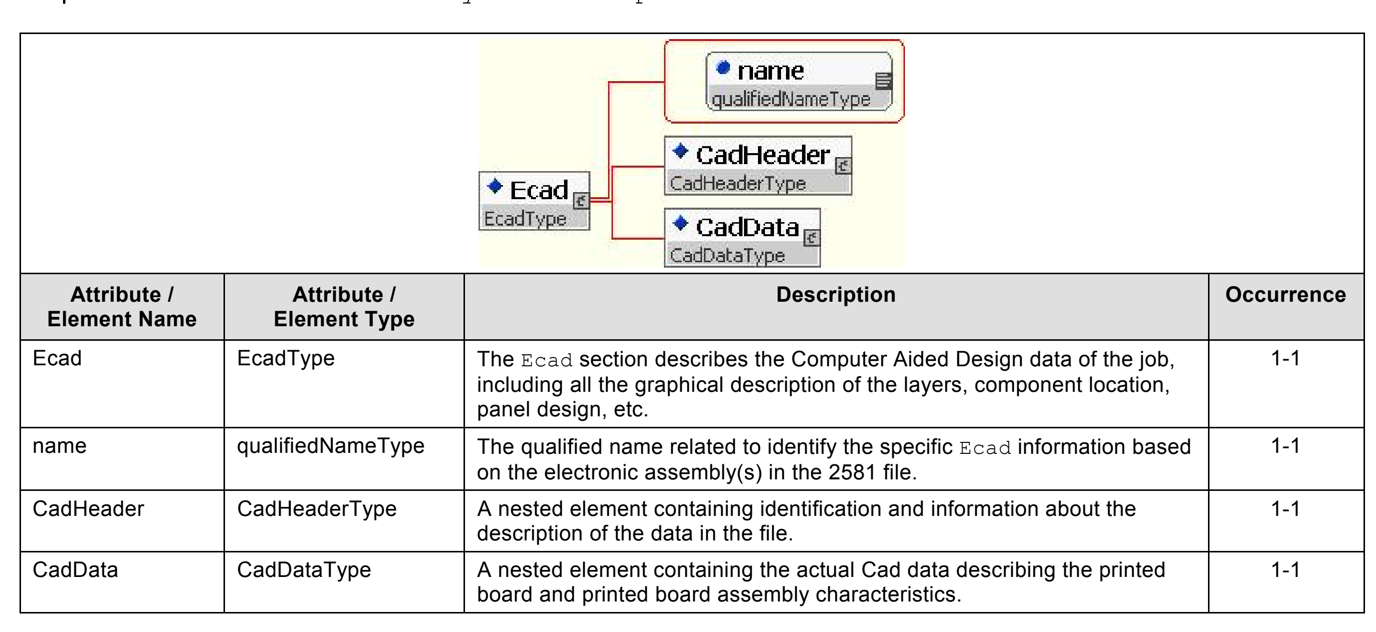
The `Textual` elements are those properties that when linked together describe the textual value of a `BomItem` as well as the source of that information.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Textual	TextualType	A nested element containing descriptive strings that can be linked together to describe any textual characteristics and their source for an individual `BomItem`.	0-n
definitionSource	string	The source of the information about the textual value.	0-1
textualCharacteristicName	string	A unique name applied to the characteristic.	0-1
textualCharacteristicValue	string	The textual value identified for the `BomItem`.	0-1

8 ELECTRONIC COMPUTER AIDED DESIGN (ECAD)

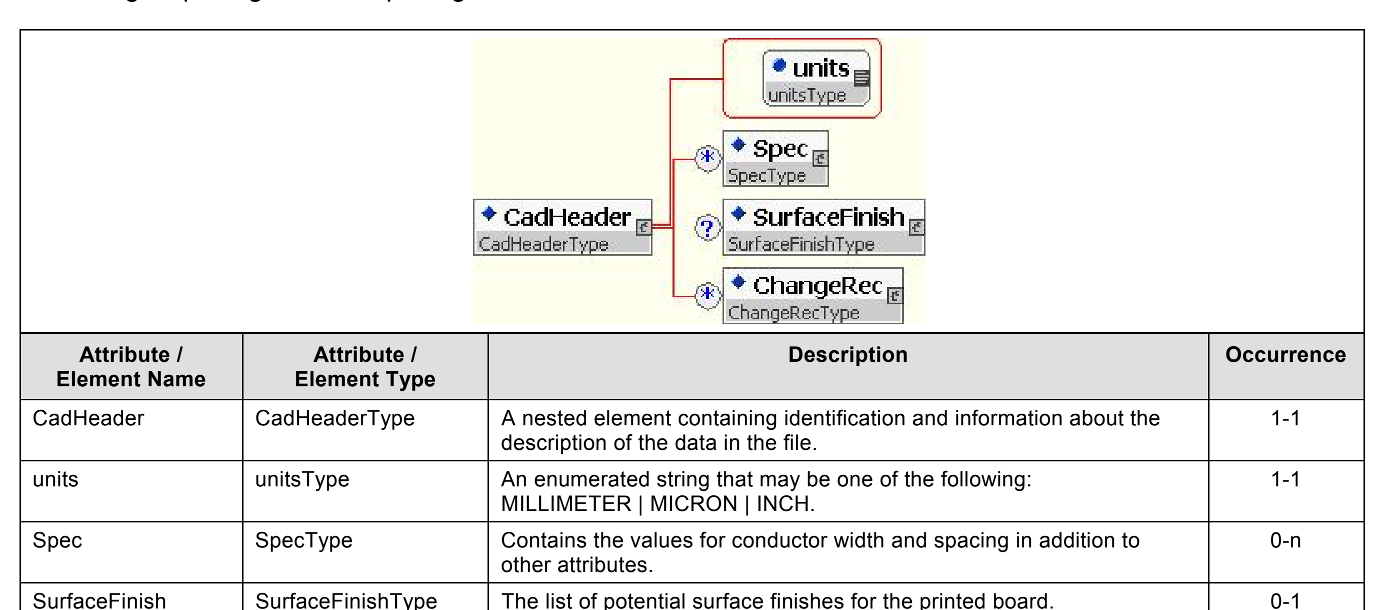
The `Ecad` section describes the Computer Aided Design data of the job, including all the graphical description of the layers, component location, panel design, etc. In most cases, the `Ecad` section is by far the largest body of data inside the 2581 file. To understand how the `Ecad` section is organized, it is important to be familiar with the `Layers` and `Step` elements.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Ecad	EcadType	The `Ecad` section describes the Computer Aided Design data of the job, including all the graphical description of the layers, component location, panel design, etc.	1-1
name	qualifiedNameType	The qualified name related to identify the specific `Ecad` information based on the electronic assembly(s) in the 2581 file.	1-1
CadHeader	CadHeaderType	A nested element containing identification and information about the description of the data in the file.	1-1
CadData	CadDataType	A nested element containing the actual Cad data describing the printed board and printed board assembly characteristics.	1-1

8.1 CadHeader

The CadHeader element is mandatory. Inside the CadHeader there are general attributes that describe the board and its format. Thickness should be in inches (imperial) or mm (metric) depending on units. The thickness attribute is the overall thickness of the board used to mount the components, including all plating and over-plating.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
CadHeader	CadHeaderType	A nested element containing identification and information about the description of the data in the file.	1-1
units	unitsType	An enumerated string that may be one of the following: MILLIMETER | MICRON | INCH.	1-1
Spec	SpecType	Contains the values for conductor width and spacing in addition to other attributes.	0-n
SurfaceFinish	SurfaceFinishType	The list of potential surface finishes for the printed board.	0-1
ChangeRec	ChangeRecType	A nested element containing identification and information about the description of the data in the Ecad section of the file.	0-n

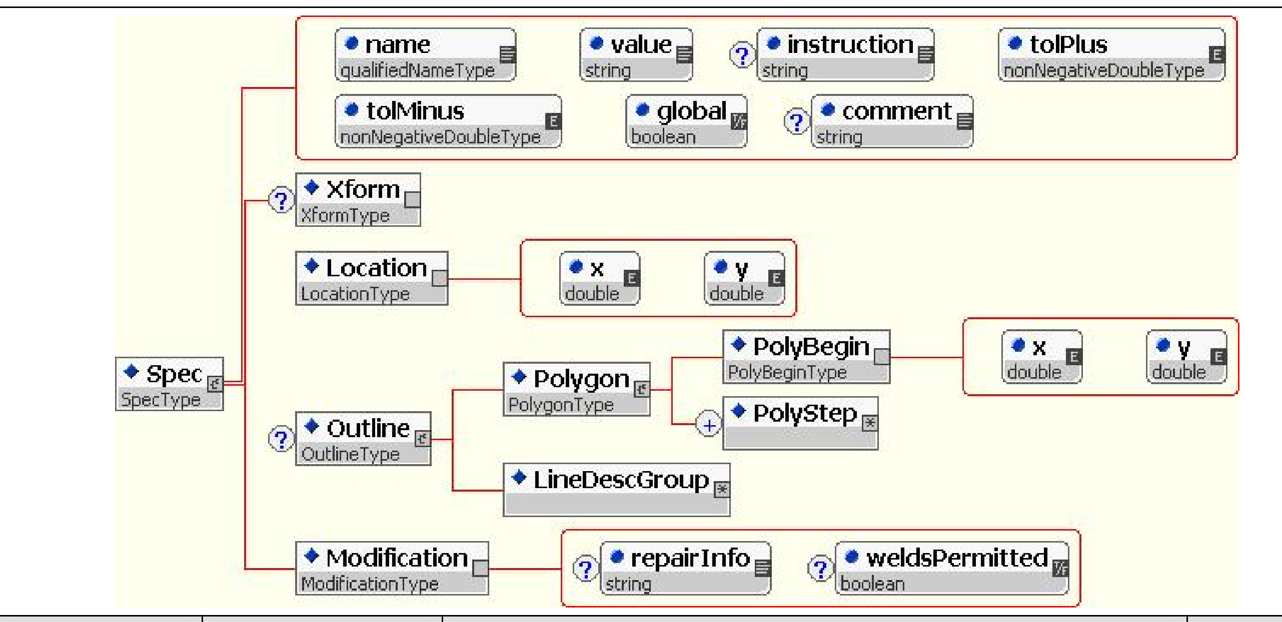
8.1.1 Spec

The Spec element contains various values for:

- width, spacing, component spacing, component to edge, etc.
- impedance, capacitance and resistance values.
- dimensions between edge/feature/hole to edge/feature/hole.

An optional comment can point to a Spec and version. An optional instruction can explain the measurement method, net and pin names or the type of elements between which the measurement has to be taken.

Up to two sub-elements describe the Location of the Spec measurement.

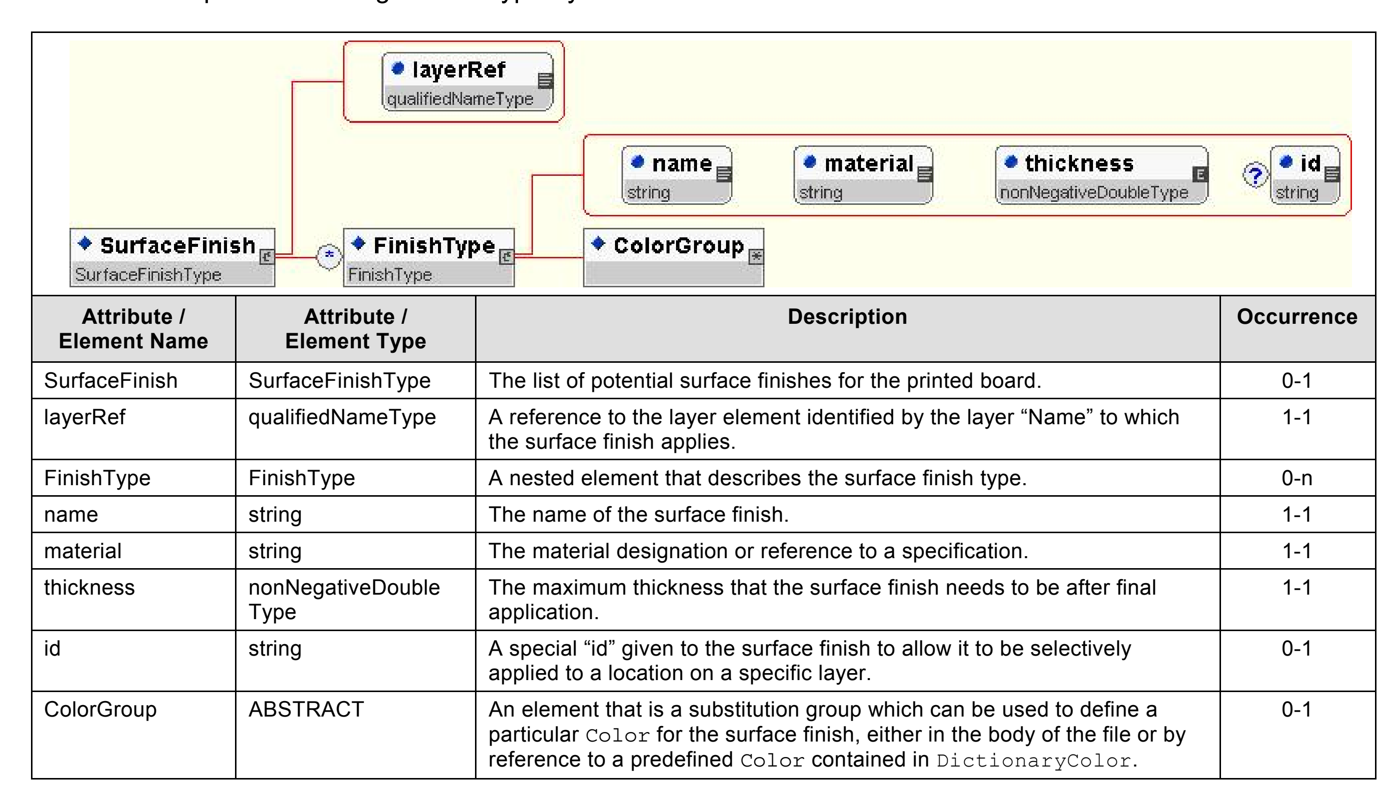


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Spec	SpecType	Contains the values for conductor width and spacing in addition to other attributes.	0-n
name	qualifiedNameType	The qualified name of the specification and indicating to which product in the file the specification pertains.	1-1
value	string	The value to be assigned to the property of the product being assessed	1-1
instruction	string	Any special instructions needed to apply the specification characteristics to the product	0-1
tolPlus	nonNegativeDouble Type	The positive tolerance to determine the upper specification limit.	1-1
tolMinus	nonNegativeDouble Type	The negative tolerance to determine the lower specification limit.	1-1
global	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that conditions apply to the entire `Ecad` data as global characteristics; False indicates that they do not.	1-1
comment	string	Any comment needed to help clarify the issues pertaining to the specification limits.	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined area that can be scaled, mirror imaged or rotated. See paragraph 3.3	0-1
Location	LocationType	The image defined by `Outline` or a pre-defined image is located to identify where the specification applies. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location to which the specification applies	1-1
y	double	The y coordinate of the location to which the specification applies	1-1
Outline	OutlineType	A nested element containing a specific area(s) to which the specification(s). The `Outline` is a closed polygon configuration	0-1
Polygon	PolygonType	The standard description for the `Polygon` characteristic must be a closed shape. The point of origin of the shape is identified as the 0:0 coordinate. The element includes the start of the polygon definition (`PolyBegin`) and the appropriate number of `PolyStep`'s to complete the closed shape. The lineWidth is through the LineDesc substitution group or defined at a time when the Polygon is instantiated.	0-n
PolyBegin	PolyBeginType	The PolyBegin element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon line.	1-1

y	double	The Y starting point of the first polygon line.	1-1
PolyStep	ABSTRACT	The PolyStep element is a substitution group that defines a circular (PolyStepCurve) or straight line (PolyStepSegment) continuation of the polygon. The polystep direction may be clockwise or counterclockwise which must be consistent when any Arc description is used as one of the PolyStep elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1-n
LineDescGroup	ABSTRACT	A substitution group that specifies the LineWidth and LineEnd characteristics of the Line by reference to a predefined LineDesc or specified when the Outline is instantiated.	1-1
Modification	ModificationType	An element that defines the acceptable modifications that may be accomplished to the final physical product.	
repairInfo	string	Information on the type of repairs permitted to the printed board.	0-1
weldsPermitted	boolean	An enumerated string that defines whether welds are permitted and may be one of the following YES; NO; or UNKNOWN.	0-1

8.1.2 SurfaceFinish

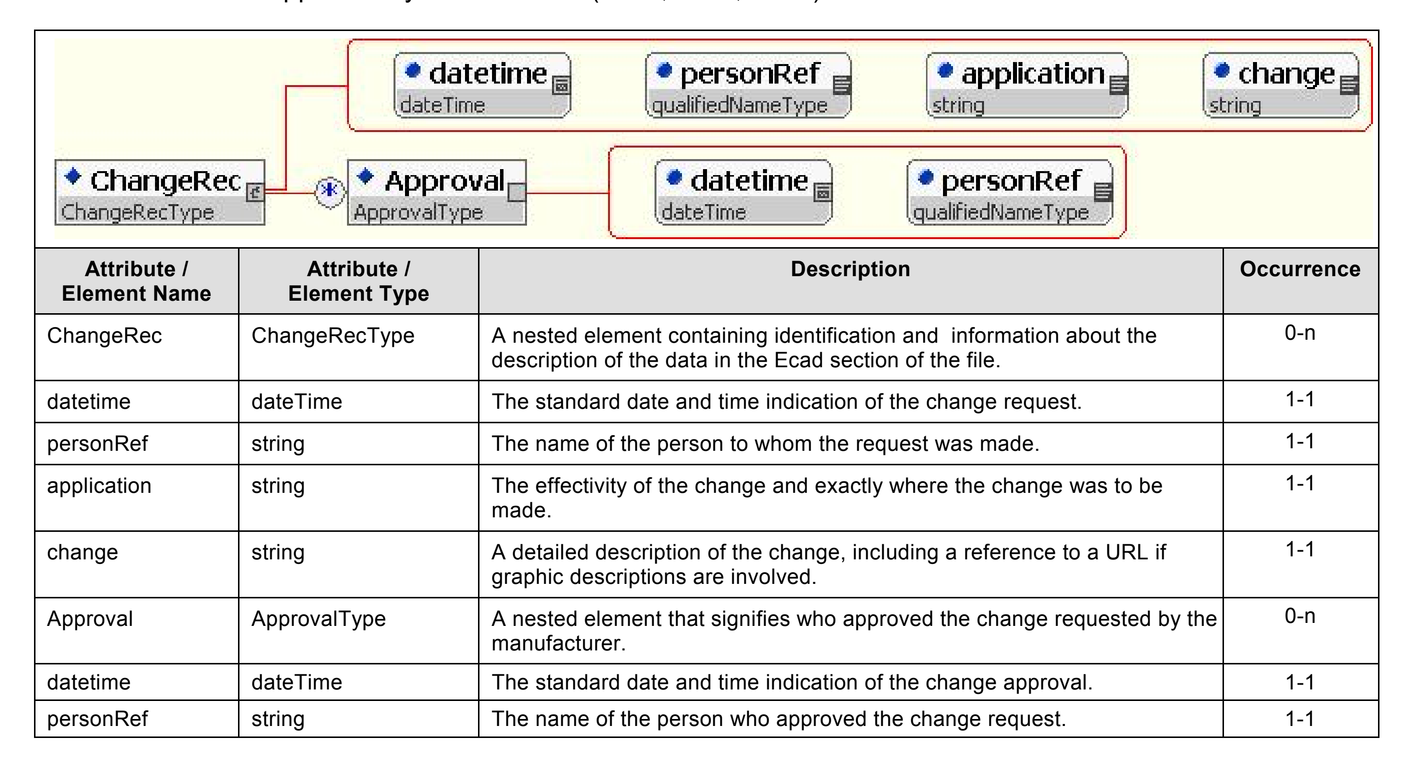
The SurfaceFinish element contains a list of potential surface finish choices and a name of a layer to which the finishes pertains. Location attributes can also be referenced by the name of the attribute to where the finish needs to be applied. These are usually in the form of polygons, each having an attribute that points to the right finish type by its id.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
SurfaceFinish	SurfaceFinishType	The list of potential surface finishes for the printed board.	0-1
layerRef	qualifiedNameType	A reference to the layer element identified by the layer "Name" to which the surface finish applies.	1-1
FinishType	FinishType	A nested element that describes the surface finish type.	0-n
name	string	The name of the surface finish.	1-1
material	string	The material designation or reference to a specification.	1-1
thickness	nonNegativeDouble Type	The maximum thickness that the surface finish needs to be after final application.	1-1
id	string	A special "id" given to the surface finish to allow it to be selectively applied to a location on a specific layer.	0-1
ColorGroup	ABSTRACT	An element that is a substitution group which can be used to define a particular Color for the surface finish, either in the body of the file or by reference to a predefined Color contained in DictionaryColor.	0-1

8.1.3 ChangeRec

The ChangeRec element contains the ChangeRec elements specifying deviations requested by the manufacturer and approved by the customer (OEM, EMS, other).



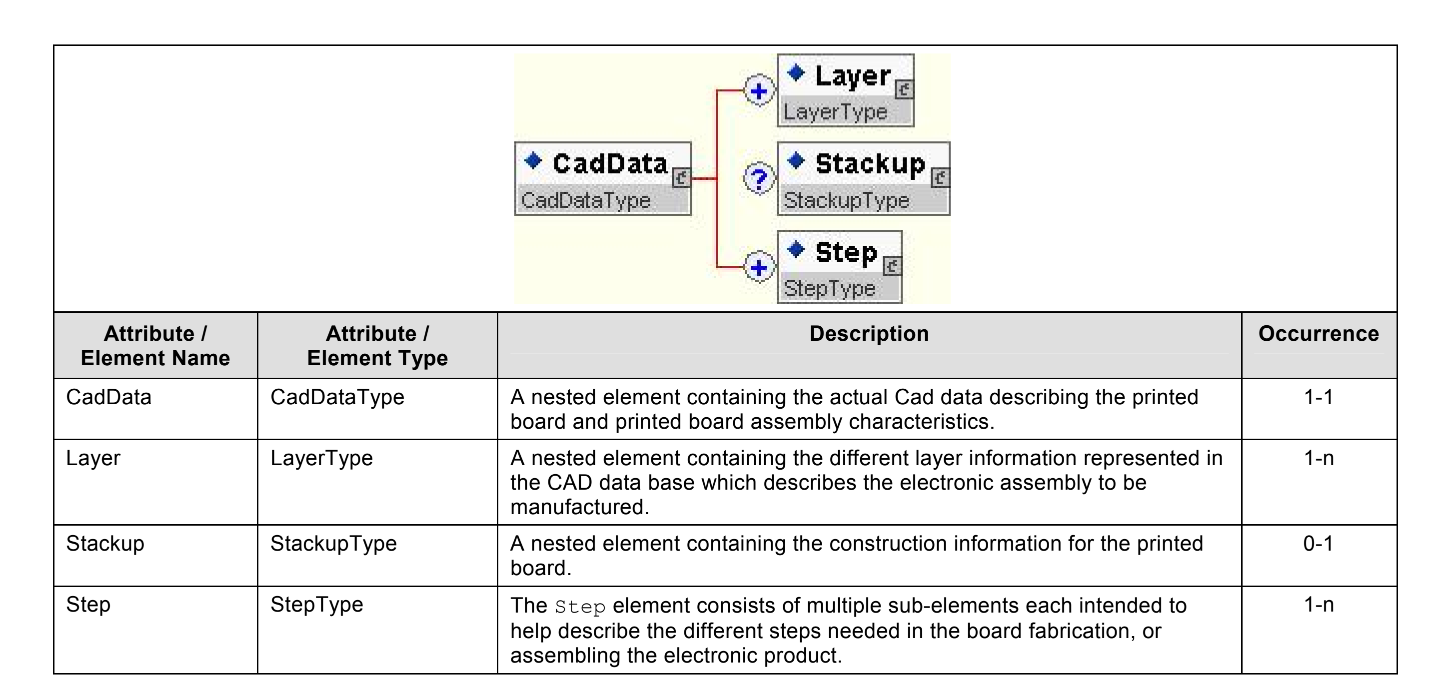
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
ChangeRec	ChangeRecType	A nested element containing identification and information about the description of the data in the Ecad section of the file.	0-n
datetime	dateTime	The standard date and time indication of the change request.	1-1
personRef	string	The name of the person to whom the request was made.	1-1
application	string	The effectivity of the change and exactly where the change was to be made.	1-1
change	string	A detailed description of the change, including a reference to a URL if graphic descriptions are involved.	1-1
Approval	ApprovalType	A nested element that signifies who approved the change requested by the manufacturer.	0-n
datetime	dateTime	The standard date and time indication of the change approval.	1-1
personRef	string	The name of the person who approved the change request.	1-1

8.2 CadData

The CadData element is the three-dimensional structure of the design that is retrieved from the Cad system as a group of layers. The information is contained in the Layer elements. The layers are listed in the correct order inside CadData and are grouped by name, context and layerFunction.

Layers are also identified by name, context, type, side, polarity, span, and DrillToolList that define each layer. CAD data layers are required in 2581 to succesfully hold ECAD layout information. These layers are not necessarily physical layers, but the myriad of layers that can be represented in the Ecad data but not actually fabricated into the bare board.

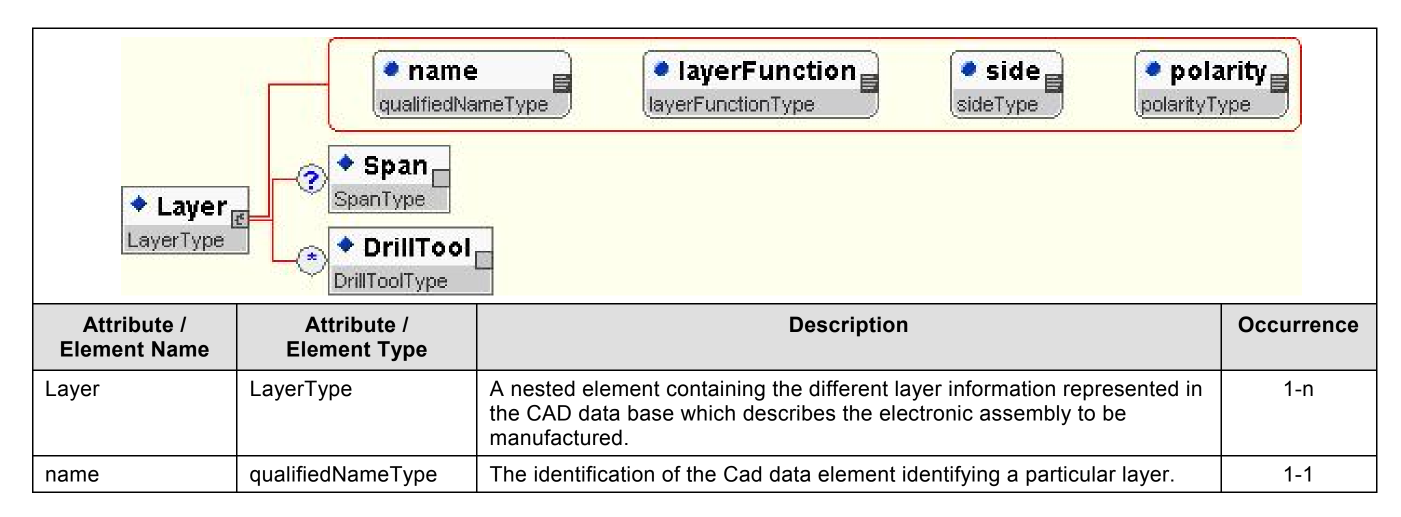
Layers, as the name implies, are sheets of two-dimensional data which, when laid on top of each other, create the Printed Circuit Assembly (unpopulated PCB and components or other related information). Some layers are physical layers that are laminated together to form the board. Other layers represent masks, films or phototools used to expose the board in a process that applies materials selectively on the outer layers of the boards. Some layers contain only drawings and annotations, which are not put physically on the board but can be used to further define it. These layers are organized in the IPC-2581 file by their specific type.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
CadData	CadDataType	A nested element containing the actual Cad data describing the printed board and printed board assembly characteristics.	1-1
Layer	LayerType	A nested element containing the different layer information represented in the CAD data base which describes the electronic assembly to be manufactured.	1-n
Stackup	StackupType	A nested element containing the construction information for the printed board.	0-1
Step	StepType	The `Step` element consists of multiple sub-elements each intended to help describe the different steps needed in the board fabrication, or assembling the electronic product.	1-n

8.2.1 Layer

The `Layer` element describes the characteristics of specific layers. The layers may be for the board or the assembly and may be individual characterization or those of the board fabrication panel and the arrangement of boards in the assembly pallet. There are also documentation, tooling and miscellaneous layers. The `layerFunction` helps to identify the purpose of the layer.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Layer	LayerType	A nested element containing the different layer information represented in the CAD data base which describes the electronic assembly to be manufactured.	1-n
name	qualifiedNameType	The identification of the Cad data element identifying a particular layer.	1-1

layerFunction	layerFunctionType	The type of layer and its main use as established by the following: For MATERIAL use: COATINGCOND | COATINGNONCOND | DIELBASE | DIELCORE | DIELPREG | DIELADHV | SOLDERBUMP | RESISTIVE | CAPACITIVE. For BOARD use: LEGEND | SOLDERMASK | CONDUCTOR | PLANE | PASTEMASK | EMBEDDED COMPONENT | DRILL| ROUTE| CONDUCTIVE_ADHESIVE. For PROCESS use: GLUE | SOLDERBUMP | HOLEFILL | PROBE | REWORK | FIXTURE| EDGE_PAINTING | COATINGCOND | COATINGNONCOND | ASSEMBLY. For DOCUMENTATION use: COURTYARD| GRAPHIC | DRAWING | LANDPATTERN | COMPONENT_TOP | COMPONENT_BOTTOM | OTHER.	1-1
side	sideType	A fixed field parameter that defines the side of the layer. The fixed attribute is one of the following TOP | BOTTOM | BOTH | INTERNAL | ALL | NOTAPPLICABLE.	1-1
polarity	polarityType	Applies for layers of type signal, power_ground or mixed. In such layers, positive means that the layer features represent copper. NEGATIVE means that the layer features represent laminate. For example, on a negative power_round layer, features represent clearances. All other layers should be defined as positive. POSITIVE is the default.	1-1
Span	SpanType	A nested element where the field may be added to layers of type drill and route that are either buried or blind. In such a case, it represents the start and end board layers between which drilling/routing is done. If the drill layer is going through the board, it is required not to be include a span subsection.	0-1
DrillTool	DrillToolType	A nested element containing drill tool and tolerance data.	0-n

There is a close relationship between the `Layer` and `Step` elements of the 2581 format. The correlation exists between the `Step` elements and attributes and the `layerFunction` attribute of the particular layer.

In general, the `Step` elements and their respective attributes have a significant purpose. Since there may be many steps in a 2581 file, users usually identify the step `name` attribute as a method to group steps that relate to a particular purpose. The following are the recommended organizational structures:

BOARD for all the ‘important’ steps representing the graphics of the board itself.

BOARDPANEL for all the ‘important’ steps representing the graphics of the board panel itself.

ASSEMBLY for all the ‘important’ steps representing the graphics of the assembly itself.

ASSEMBLYPALLET for all the ‘important’ steps representing the graphics of the assembly pallet itself.

DOCUMENTATION for all the ‘important’ steps representing the documentation of the board or the assembly.

TOOLING for all the ‘important’ steps representing the tooling used on the board or the assembly.

COUPON for test coupons that are embedded in the design of the board or assembly.

MISCELLANEOUS, for all the remaining steps that do not have a home in any of the other context identification.

The purpose of a group of step elements should relate to the layer descriptions which are identified by their attributes that include the mandatory requirements of name, layerFunction, side, and polarity. Due to the layerRef attributes of several Step elements, the recommendations shown in Table 5 apply to good file management. Table 5 shows all possible combinations of the layerFunction attributes and their potential characteristics. Table 5-1 indicates the recommendations of layer attributes to the Step elements that are intended to describe the board or board panel. Table 5-2 shows the

recommendations related to assembly and assembly pallet. Table 5-3 shows the recommendations related to the coupon step elements. Step documentation, tooling, and miscellaneous element recommendations are shown in Table 5-4.

Table 5 Step Elements to Layer Attribute Recommendations

Step elements that describe:	Layer Attributes				
	name	layerFunction		side letters for reference only	Polarity numbers for reference only
All Possible Combinations	A unique name in a 2581 file	MATERIAL	COATINGCONDMAT COATINGNONCONDMAT DIELBASE DIELCORE DIELPREG DIELADHV SOLDERBUMP RESISTIVE CAPACITIVE. CONDFOIL CONDFILM	A_TOP B_BOTTOM C_BOTH D_INTERNAL E_ALL F_OTHER	1-POSITIVE 2 NEGATIVE
		BOARD	LEGEND SOLDERMASK CONDUCTOR PLANE PASTEMASK EMBEDDED COMPONENT DRILL ROUTE CONDUCTIVE_ADHESIVE.	A_TOP B_BOTTOM C_BOTH D_INTERNAL E_ALL F_ OTHER	1- POSITIVE 2-NEGATIVE
		PROCESS	GLUE SOLDERBUMP HOLEFILL PROBE REWORKFIXTURE EDGE_PAINTING COATINGCOND COATINGNONCOND ASSEMBLY.	A_TOP B_BOTTOM C_BOTH D_INTERNAL E_ALL F_ OTHER	1- POSITIVE 2-NEGATIVE
		DOCUMENTATION	COURTYARD GRAPHIC DRAWING LANDPATTERN COMPONENT_TOP COMPONENT_BOTTOM OTHER	A_TOP B_BOTTOM C_BOTH D_INTERNAL E_ALL F_ OTHER	1- POSITIVE 2-NEGATIVE

Table 5-1 Step Elements to Layer Attribute Recommendations for Board or Board Panel

Step elements that describe:	Layer Attributes				
	name	layerFunction		side letters for reference only	Polarity numbers for reference only
BOARD AND BOARD PANEL	A unique name in a 2581 file	MATERIAL	COATINGCONDMAT	A|B|C|D|E	1
			COATINGNONCONDMAT	A|B|C|D|E	1|2
			DIELBASE	A|B|C|D	1|2
			DIELCORE	A|B|C|D	1|2
			DIELPREG	D	1|2
			DIELADHV	A|B|C|D	1
			SOLDERBUMP	A|B|C|D	1|2
			RESISTIVE	D	1|2
			CAPACITIVE	D	1|2
			CONDFOIL	A|B|C|D|E	1|2
			CONDFILM	A|B|C|D|E	1|2
		BOARD	LEGEND.	A|B|C|D	1|2
			SOLDERMASK	A|B|C|	1|2
			CONDUCTOR	A|B|C|D	1|2
			PLANE	A|B|C|D	1|2
			PASTEMASK	A|B|C	1|2
			EMBEDDED COMPONENT	D	1
			DRILL	A|B|C|D|E	1
			ROUTE	A|B|C|D|E	1|2
			CONDUCTIVE_ADHESIVE	A|B|C|D	1
		PROCESS	GLUE	A|B	1
			SOLDERBUMP	A|B	1
			HOLEFILL	A|B|C	1
			PROBE	A|B|C	1
			REWORKFIXTURE	F	1
			EDGE_PAINTING	F	1
			COATINGCOND	A|B|C|D|E	1
			COATINGNONCOND	A|B|C|D|E	1|2
			ASSEMBLY.	F	1
		DOCUMENTATION	COURTYARD	F	1
			GRAPHIC	A|B|C|D|E	1|2
			DRAWING	A|B|C|D|E	1
			LANDPATTERN	A|B|C|D|E	1
			COMPONENT_TOP	A	1
			COMPONENT_BOTTOM	B	1
			OTHER	A|B|C|D|E	1

Table 5-2 Step Elements to Layer Attribute Recommendations for Assembly and AssemblyPallet

Step elements that describe:	Layer Attributes				
	name	layerFunction		Side letters for reference only	Polarity numbers for reference only
ASSEMBLY AND ASSEMBLY PALLET	A unique name in a 2581 file	MATERIAL	COATINGCONDMAT	A|B|C|E	1
			COATINGNONCONDMAT	A|B|C|E	1
			DIELADHV	A|B|C	1
			SOLDERBUMP	A|B	1
			RESISTIVE	A|B|C	1
			CAPACITIVE	A|B|C	1
		BOARD	PASTEMASK	A|B|C	1|2
			EMBEDDED COMPONENT	A|B|C	1|2
			CONDUCTIVE_ADHESIVE	A|B|C	1
		PROCESS	GLUE	A|B	1|2
			SOLDERBUMP	A|B	1|2
			PROBE	A|B|C	1|2
			REWORKFIXTURE	F	1
			COATINGNONCOND	A|B|C|D|E	1|2
			ASSEMBLY.	A|B|C|D|E	1|2
		DOCUMENTATION	COURTYARD	A|B|C	1
			GRAPHIC	A|B|C|D|E	1|2
			DRAWING	A|B|C|D|E	1
			COMPONENT_TOP	A	1
			COMPONENT_BOTTOM	B	1
			OTHER	A|B|C|D|E	1

Table 5-3 Step Element to Layer Attribute Recommendations for Coupon

Step elements that describe:	Layer Attributes				
	name	layerFunction		Side letters for reference only	Polarity numbers for reference only
COUPON	A unique name in a 2581 file	MATERIAL	COATINGCONDMAT	A|B|C|D|E	1
			COATINGNONCONDMAT	A|B|C|D|E	1|2
			DIELBASE	A|B|C|D	1|2
			DIELCORE	A|B|C|D	1|2
			DIELPREG	D	1|2
			DIELADHV	A|B|C|D	1
			RESISTIVE	D	1|2
			CAPACITIVE	D	1|2
			CONDFOIL	A|B|C|D|E	1|2
			CONDFILM	A|B|C|D|E	1|2
			LEGEND.	A|B|C|D	1|2
		BOARD	SOLDERMASK	A|B|C|	1|2
			CONDUCTOR	A|B|C|D	1|2
			PLANE	A|B|C|D	1|2
			EMBEDDED COMPONENT	D	1
			DRILL	A|B|C|D|E	1
			ROUTE	A|B|C|D|E	1|2
		PROCESS	GLUE	A|B	1
			SOLDERBUMP	A|B	1
			HOLEFILL	A|B|C	1
			PROBE	A|B|C	1
			REWORKFIXTURE	F	1
			EDGE_PAINTING	F	1
			COATINGCOND	A|B|C|D|E	1
			COATINGNONCOND	A|B|C|D|E	1|2
			ASSEMBLY.	F	1
		DOCUMENTATION	COURTYARD	F	1
			GRAPHIC	A|B|C|D|E	1|2
			DRAWING	A|B|C|D|E	1
			LANDPATTERN	A|B|C|D|E	1
			COMPONENT_TOP	A	1
			COMPONENT_BOTTOM	B	1
			OTHER	A|B|C|D|E	1

Table 5-4 Step Purpose to Layer Restrictions for Documentation, Tooling and Miscellaneous

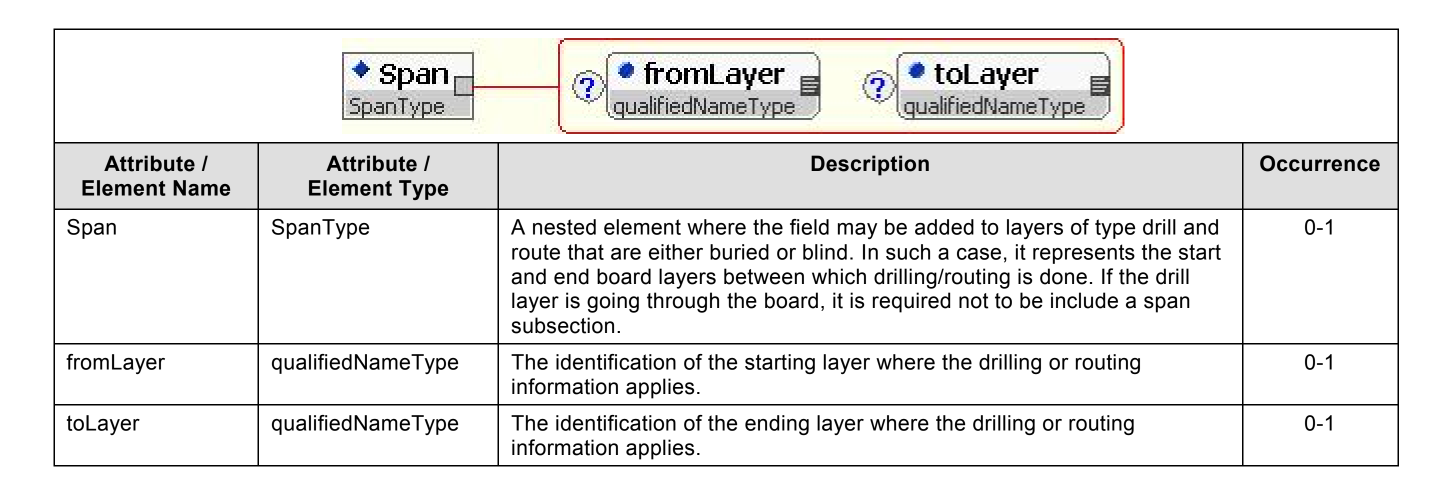
Step elements that describe:	Layer Attributes				
	name	layerFunction		Side letters for reference only	Polarity numbers for reference only
DOCUMENTATION	A unique name in a 2581 file	DOCUMENTATION	COURTYARD	A|B|C	1
			GRAPHIC	A|B|C|D|E	1|2
			DRAWING	A|B|C|D|E	1
			COMPONENT_TOP	A	1
			COMPONENT_BOTTOM	B	1
			OTHER	A|B|C|D|E	1
TOOLING	A unique name in a 2581 file	PROCESS	GLUE	A|B|C	1|2
			SOLDERBUMP	A|B	1|2
			PROBE	A|B	1
			REWORKFIXTURE	A|B|C	1
			COATINGNONCOND	A|B	1
MISCELLANEOUS	A unique name in a 2581 file	DOCUMENTATION	OTHER	A|B|C|D|E|F	1

When combining steps that describe BOARD and COUPON information on the same PANEL, the layer construction **shall** be identical between those elements being instantiated on the same panel. They also refer to the layering so that it is consistent such that the top layer is identical for all steps referenced in the panel construction.

The viewer should always display the graphical features but store the layer polarity as an attribute.

8.2.1.1 Span

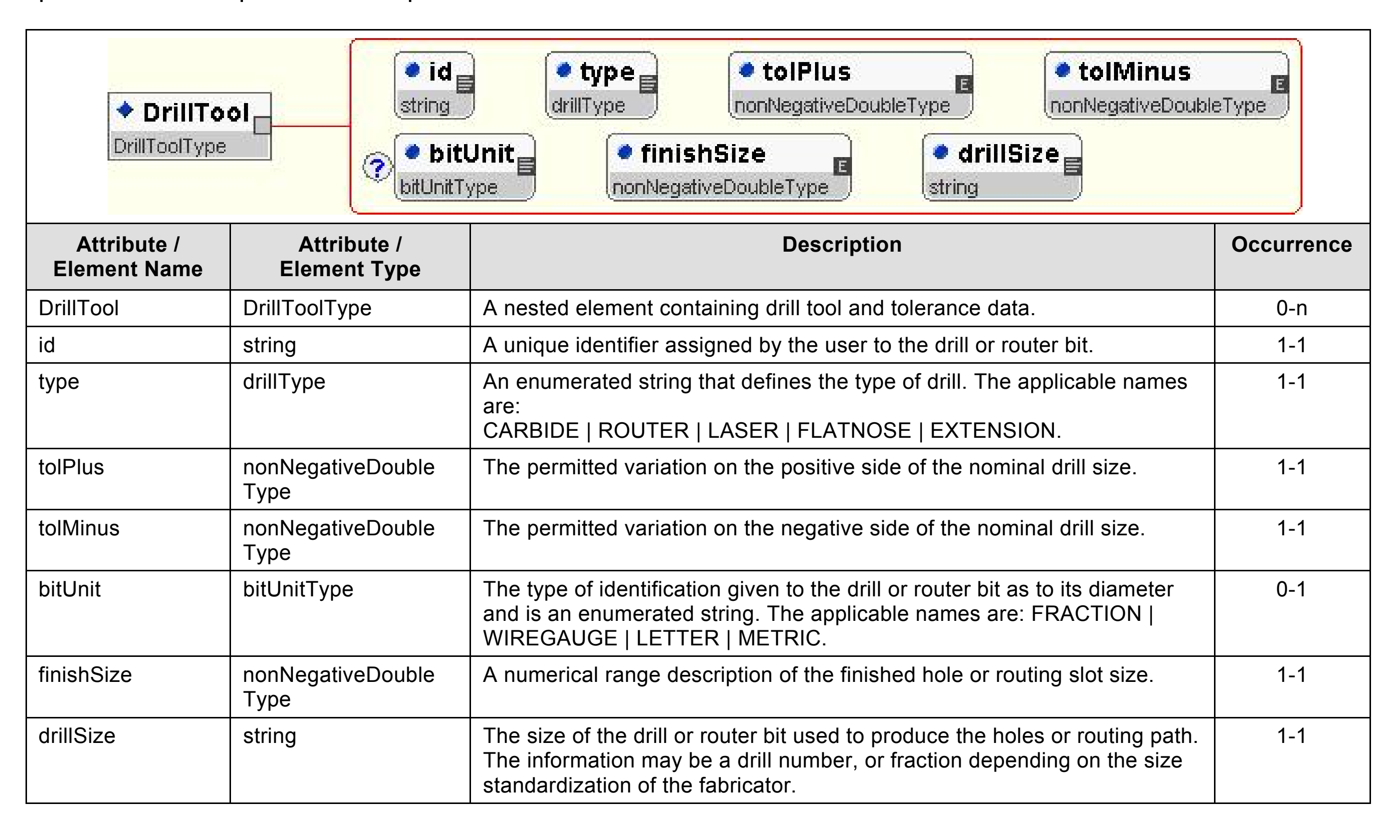
The `Span` element is relevant only for layers of type drill (holes drilled in the board) and rout (final cut around the outline of the board). The span defines the layers through which the drill/rout is done. `Span` **shall not** be used for holes that are drilled through the entire board; The `Span` element is used to define drilling for board construction subsets, or sequential lamination processes.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Span	SpanType	A nested element where the field may be added to layers of type drill and route that are either buried or blind. In such a case, it represents the start and end board layers between which drilling/routing is done. If the drill layer is going through the board, it is required not to be include a span subsection.	0-1
fromLayer	qualifiedNameType	The identification of the starting layer where the drilling or routing information applies.	0-1
toLayer	qualifiedNameType	The identification of the ending layer where the drilling or routing information applies.	0-1

8.2.1.2 DrillTool

The `DrillTool` is the list of elements and their tolerances used in the drill and rout layers of the final printed board or printed board panel



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DrillTool	DrillToolType	A nested element containing drill tool and tolerance data.	0-n
id	string	A unique identifier assigned by the user to the drill or router bit.	1-1
type	drillType	An enumerated string that defines the type of drill. The applicable names are: CARBIDE | ROUTER | LASER | FLATNOSE | EXTENSION.	1-1
tolPlus	nonNegativeDouble Type	The permitted variation on the positive side of the nominal drill size.	1-1
tolMinus	nonNegativeDouble Type	The permitted variation on the negative side of the nominal drill size.	1-1
bitUnit	bitUnitType	The type of identification given to the drill or router bit as to its diameter and is an enumerated string. The applicable names are: FRACTION | WIREGAUGE | LETTER | METRIC.	0-1
finishSize	nonNegativeDouble Type	A numerical range description of the finished hole or routing slot size.	1-1
drillSize	string	The size of the drill or router bit used to produce the holes or routing path. The information may be a drill number, or fraction depending on the size standardization of the fabricator.	1-1

Typically, a hole is drilled through the whole board, thus no `span` is defined. However, in more complex designs, a subset of the layers is drilled separately, and then laminated with the rest of the layers. The drills are then called blind or buried vias. Separate layers will contain the holes of these kinds and the `span` for these layers is set accordingly.

8.2.2 Stackup

The `Stackup` element represents the construction for the printed board. The `Stackup` element consists of several sub-elements that help to define various sections of the construction permitting the

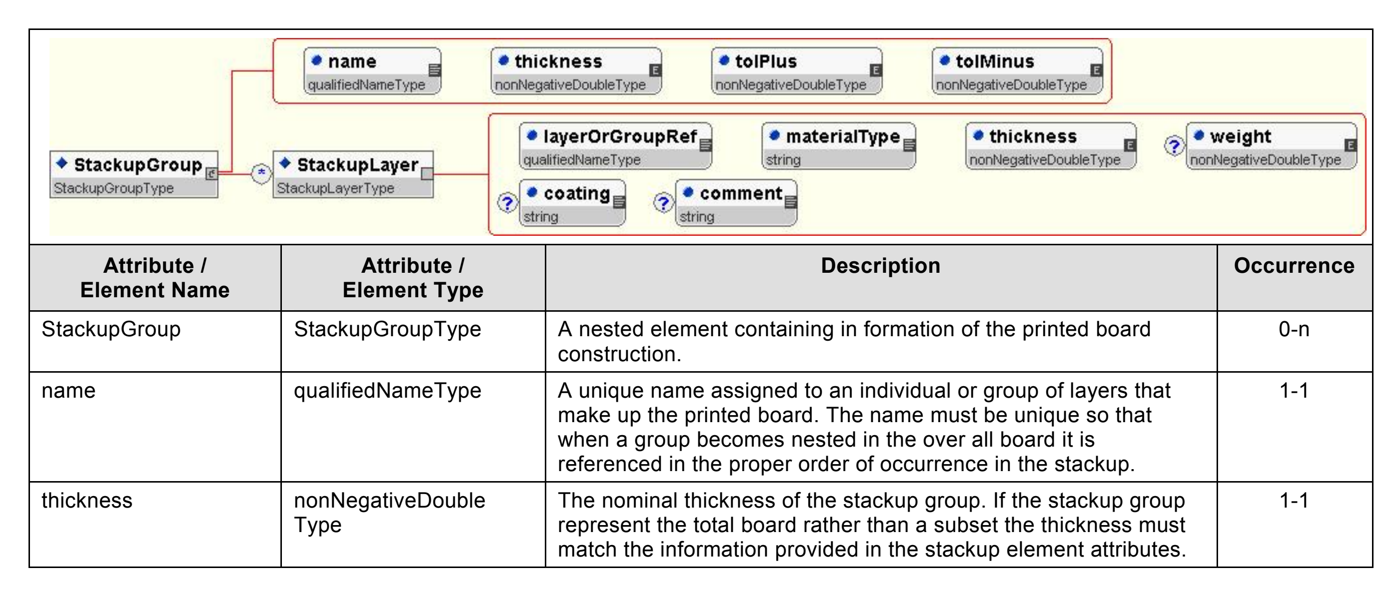
description of core material or prepreg definition. These are accomplished in the `StackupGroup` element.

Stackup StackupType
overallThickness nonNegativeDoubleType
tolPlus nonNegativeDoubleType
tolMinus nonNegativeDoubleType
whereMeasured whereMeasuredType
StackupGroup StackupGroupType
StackupImpedance StackupImpedanceType

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Stackup	StackupType	A nested element containing the construction information for the printed board.	0-1
overallThickness	nonNegativeDouble Type	Describes the overall nominal thickness of the finished printed board including all plating and coatings.	1-1
tolPlus	nonNegativeDouble Type	The plus tolerance that may be applied to the nominal thickness to set the printed board upper control limit.	1-1
tolMinus	nonNegativeDouble Type	The minus tolerance that may be applied to the nominal thickness to set the printed board lower control limit.	1-1
whereMeasured	whereMeasuredType	An enumerated string that may be one of the following: LAMINATE | METAL | MASK | OTHER that defines the location on the printed board, panel, or assembly where the overall thickness is to be measured.	1-1
StackupGroup	StackupGroupType	A nested element containing in formation of the printed board construction.	0-n
StackupImpedance	StackupImpedance Type	A nested element containing information on those areas that a sensitive to impedance matching and must therefore be controlled to achieve the desired results.	0-n

8.2.2.1 StackupGroup

The `StackupGroup` represents all the layers of the printed board and defines the order of their occurrence in the board construction. Individual layers may be identified as layer pairs. In this manner the user has the ability to define the characterization of the multilayer construction as well as preparing layer prelamination sequences. The order, however, must be in accordance with the description of the final board.



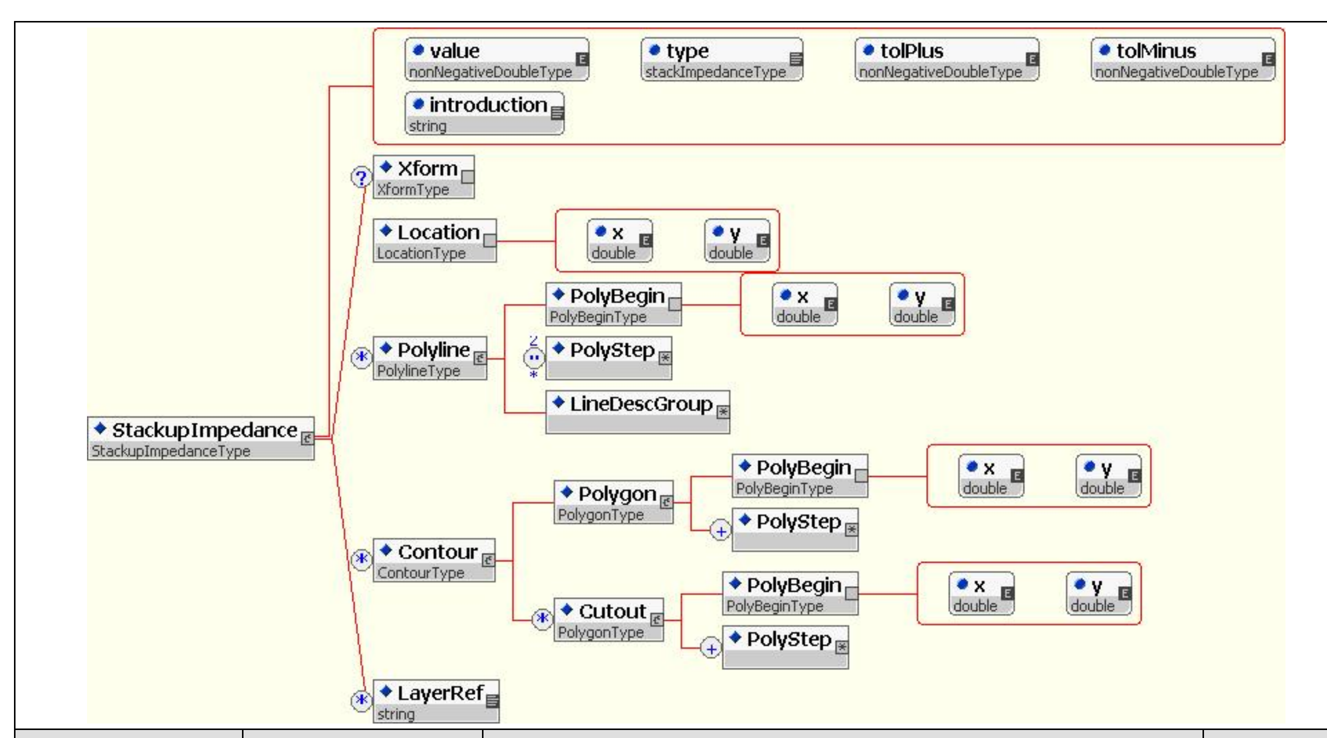
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StackupGroup	StackupGroupType	A nested element containing in formation of the printed board construction.	0-n
name	qualifiedNameType	A unique name assigned to an individual or group of layers that make up the printed board. The name must be unique so that when a group becomes nested in the over all board it is referenced in the proper order of occurrence in the stackup.	1-1
thickness	nonNegativeDouble Type	The nominal thickness of the stackup group. If the stackup group represent the total board rather than a subset the thickness must match the information provided in the stackup element attributes.	1-1

tolPlus	nonNegativeDouble Type	The plus tolerance that may be applied to the nominal thickness to set the stackupGroup upper control limit.	1-1
tolMinus	nonNegativeDouble Type	The minus tolerance that may be applied to the nominal thickness to set the stackupGroup lower control limit.	1-1
StackupLayer	StackupLayerType	A nested element containing in all the layer formation as to how the printed board is constructed. If layer pairs are produced separately possibly containing buried vias they are defined as a separate group and then positioned in the appropriate order of their occurrence in the stackup.	0-n
LayerOrGroupRef	qualifiedNameType	A reference to an individual layer or a group that has been previously identified. A single sheet of copper foil may be a named layer and would thus apply to the group, as would a layer pair of copper clad laminate purchased from a laminator.	1-1
materialType	string	Identification of the material in the stackup. The material may be conductive or nonconductive, film, adhesive, prepreg, copper foil or metal core.	1-1
thickness	nonNegativeDouble Type	The thickness of the particular material being defined. The thickness matches nominal thickness of a predefined StackupGroup.	1-1
weight	nonNegativeDouble Type	An optional attribute mostly used to define starting copper foil or metal cores which are measured in ounces.	0-1
coating	string	An optional attribute used to define special coating used in the stackup, such as adhesives, solder mask or selective conformal coating.	0-1
comment	string	An optional attribute used to provide any special instructions about the layering or stackup of a multilayer single-sided, or double-sided printed board.	0-1

8.2.2.2 StackupImpedance

The `StackupImpedance` element defines the circuits that have impedance control requirements. The elements and descriptions define those circuits contained in the design that must meet the requirements of impedance control. These characteristics are a function of the design intent and may not necessarily reflect the final characteristics of the conductor topology or stackup hierarchy identified in Layers and/or Step. The information reflects the original file creation and may be used to verify that the HistoryRecord is intact.

Since the details of the XML description reflects the design requirements the information may only be changed by the file owner.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StackupImpedance	StackupImpedance Type	A nested element containing information on those areas that a sensitive to impedance matching and must therefore be controlled to achieve the desired results.	0-n
value	nonNegativeDouble Type	The numeric value in Z ohms trying to be achieved for the circuit that is defined in the StackupImpedance element.	1-1
type	StackImpedance Type	The enumerated string that defines the type as being either MICROSTRIP | DIFFERENTIAL_PAIR | EMBEDDED_MICROSTRIP | EDGE_COUPLED_STRIPLINE | DECOUPLED_EMBEDDED_MICROSTRIP | RAMBUS | COPLANAR_WAVEGUIDE_MICROSTRIP | COPLANAR_WAVEGUIDE_STRIPLINE | EDGE_COUPLED_COPLANAR_WAVEGUIDE_STRIPLINE | EDGE_COUPLED_COPLANAR_WAVEGUIDE_MICROSTRIP that requires the impedance control.	1-1
tolPlus	nonNegativeDouble Type	The plus tolerance on the nominal number established as the value for the impedance circuitry.	1-1
tolMinus	nonNegativeDouble Type	The minus tolerance on the nominal number established as the value for the impedance circuitry.	1-1
introduction	string	The details required to identify the source and receptor of the signals that need the control and whether the construction is a Stripline, Embedded Stripline, microstrip, dual microstrip or some other configuration.	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined area that can be scaled, mirror imaged or rotated. See paragraph 3.3. The details provide where the impedance is critical	0-1
Location	LocationType	The image defined by `Polyline` or `Contour` or a pre-defined image is located to identify where the impedance applies. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location to which the impedance applies	1-1
y	double	The y coordinate of the location to which the impedance applies	1-1

Polyline	PolylineType	A particular conductor that can be defined as a continuous circuit on a particular layer of reference where the conductor width or dielectric separation are part of the impedance calculations. The polyBegin and polyStep attributes are provided.	0-n
PolyBegin	PolyBeginType	The PolyBegin element defines the starting point of the polyline.	1-1
x	double	The X starting point of the first polyline line segment.	1-1
y	double	The Y starting point of the first polyline line segment.	1-1
PolyStep	ABSTRACT	The PolyStep element is a substitution group that defines a circular (PolyStepCurve) or straight line (PolyStepSegment) continuation of the polygon. The polystep direction may be clockwise or counterclockwise which must be consistent when any Arc description is used as one of the PolyStep elements. Straight or curved line segments must not cross.	2-n
LineDescGroup	ABSTRACT	A substitution group that specifies the LineWidth and LineEnd characteristics of the Line by reference to a predefined LineDesc or specified when the Polyline is instantiated.	1-1
Contour	ContourType	A sequence of connected edges that form a polygon. An edge can be straight or circular.	0-n
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon.	1-1
PolyBegin	PolyBeginType	The PolyBegin element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The PolyStep element is a substitution group that defines a circular (PolyStepCurve) or straight line (PolyStepSegment) continuation of the polygon. The polystep direction may be clockwise or counterclockwise which must be consistent when any Arc description is used as one of the PolyStep elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1-n
Cutout	CutoutType	A polygon closed shape whose edges do not cross, which adopts the coordinates of the original polygon, however represents the absence of material within the original polygon shape.	0-n
PolyBegin	PolyBeginType	The PolyBegin element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The PolyStep element is a substitution group that defines a circular (PolyStepCurve) or straight line (PolyStepSegment) continuation of the polygon. The polystep direction may be clockwise or counterclockwise which must be consistent when any Arc description is used as one of the PolyStep elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1-n
LayerRef	qualifiedNameType	A reference to the layer being described in the elements.	0-n

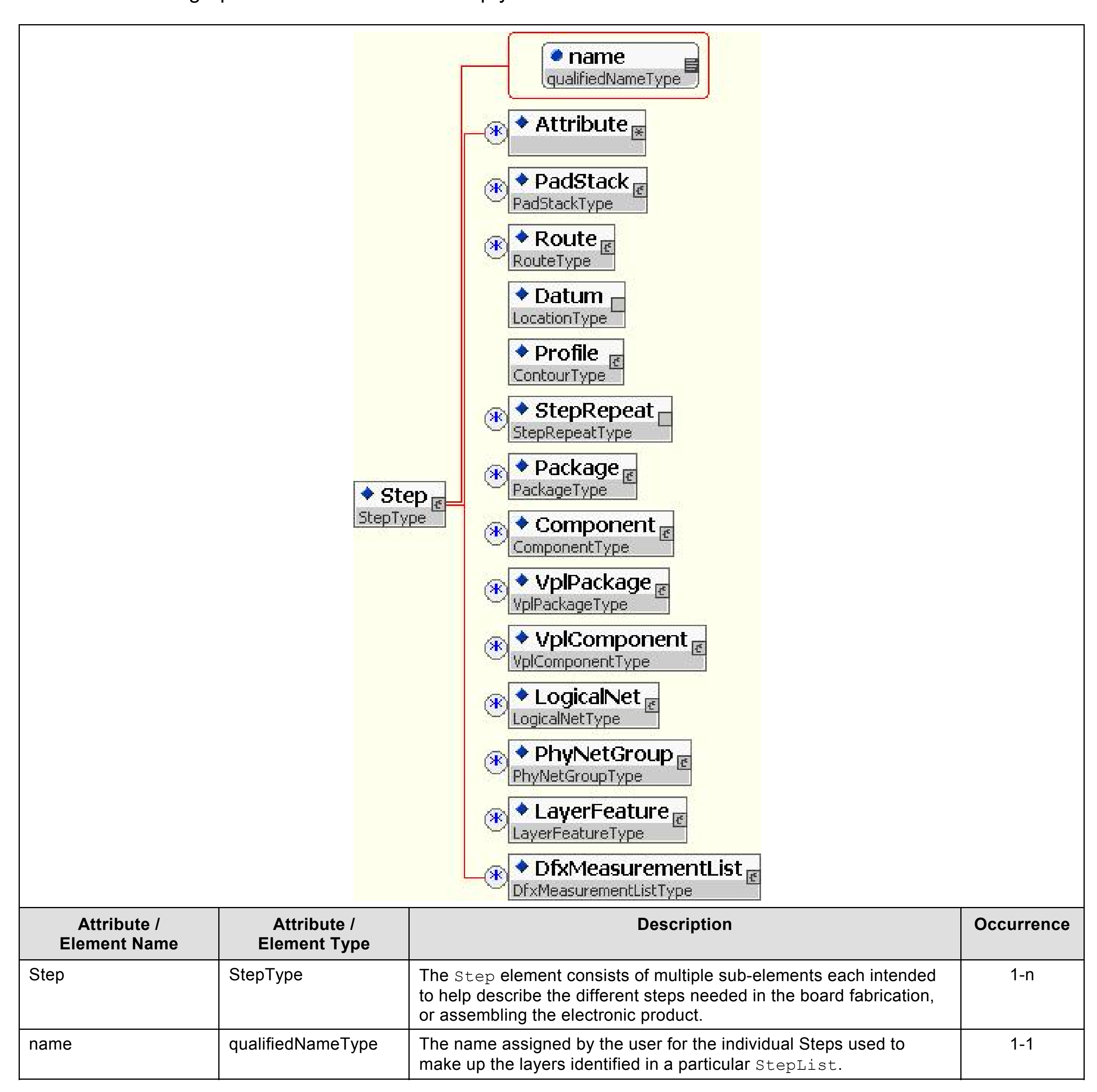
8.2.3 Step

The Step element represents a collection of layers, each with a profile that defines its outer shape. The basic step is the Printed Circuit Assembly (PCA), the unpopulated board or other related information (eg., documentation). In manufacturing, this basic step is often step and repeated (nested) inside a larger step (called array, or sub-panel). This array step can be further nested into another step; called a production panel. The Ecad element always contains at least one Step, but may contain several, some basic ones and others nesting previous steps.

The CAD Step tag can be repeated multiple times inside a job to represent several job Steps and their optional panelization. Each Step contains all the relevant information including Datum, Profile,

StepRepeat, LayerAttribute, Package, Component, VplComponent, LogicalNet and LayerFeature.

All steps inside an Ecad element share the exact same layer structure, since they are 'cut' from the same basic panel. Each layer, in the list of layers, exists in every step, although in each step it may contain different graphical information or be empty.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Step	StepType	The Step element consists of multiple sub-elements each intended to help describe the different steps needed in the board fabrication, or assembling the electronic product.	1-n
name	qualifiedNameType	The name assigned by the user for the individual Steps used to make up the layers identified in a particular StepList.	1-1

Attribute	ABSTRACT	The Attribute group consists of various identifiers that may be used within the body of the IPC-2581 standard. Attributes are optional and are used within the Component, LogicalNet, Set, and Step elements. Attributes contain legacy data that has not yet become a more formal part of IPC-2581. The use of attributes within the 2581 file should be used with caution since their purpose is to classify a unique condition. Thus, all other data under the umbrella of the parent element that references the attribute would need to reflect the identical unique condition identified by the attribute. The long range intention is to deprecate all Attributes and to incorporate their information elsewhere in IPC-2581 files. There are five kinds of standard Attributes that hold different types of data, and a NonstandardAttribute which can contain any type of data. The standard attributes are constrained to have specific names.	0-n
PadStack	PadStackType	A nested element containing a list of all the PadStack configurations taken from the CAD file as a descriptions of the original design of the board or panel and their application to the electronic product. The data is redundant when layered fabrication is defined in the file, and serves the purpose of archiving CAD data used for reference.	0-n
Route	RouteType	The individual route segment list captured from the CAD system. The data is redundant when layered fabrication is defined in the file, and serves the purpose of archiving CAD data used for reference.	0-n
Datum	LocationType	The Datum element defines the location of the point of origin for the individual Step file. The name of the StepList helps to associate the datum between boards and panels or arrays.	1-1
Profile	ContourType	The profile of all the elements in the Step established as a Contour.	1-1
StepRepeat	StepRepeatType	A nested element list containing the Step and Repeat functions that impact the information of the electronic product.	0-n
Package	PackageType	Generic component package descriptions for use by the Step file schemas.	0-n
Component	ComponentType	A nested element list of component descriptions and their application to the electronic product. Each component references a package style from the Package section.	0-n
VplPackage	VplPackageType	A nested element list of package types and CAD library descriptions and their application to the electronic product.	0-n
VplComponent	VplComponentType	A nested element list of component descriptions combined with any External Vendor Parts Library (EVPL) Database. Each component references a package style from the VplPackage section.	0-n
LogicalNet	LogicalNetType	A nested element list of logical net descriptions and their application to the electronic product.	0-n
PhyNetGroup	PhyNetGroupType	A nested element list of physical net descriptions and their application to the electronic product.	0-n
LayerFeature	LayerFeatureType	A nested element list of all the features associated with a specific layer and their application to the electronic product.	0-n
DfxMeasurementList	DfxMeasurement ListType	A nested element list of the recommended modifications of the design features, indicating the measurements made of the physical conditions that might be considered as manufacturing improvements.	0-n

8.2.3.1 Attribute

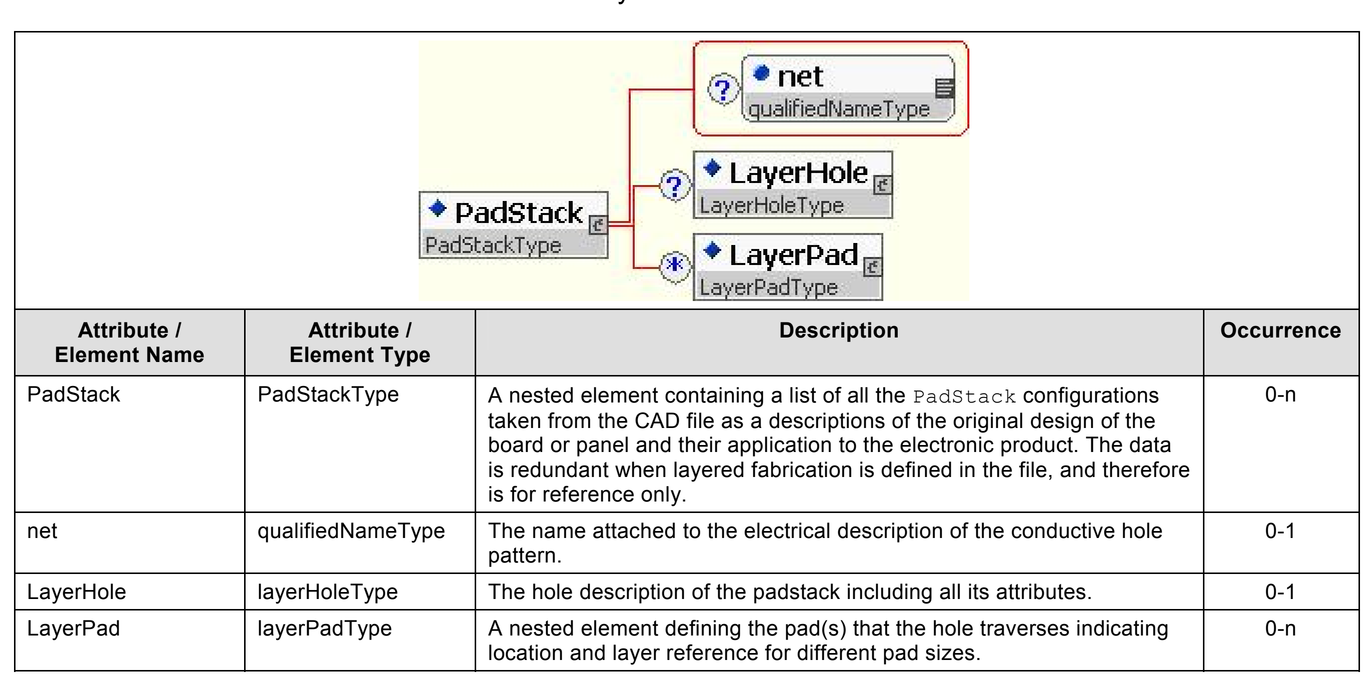
The `Attribute` group consists of various conditions that may be used in association with the `Step`. There are five kinds of standard `Attribute` that hold different types of data, and a `NonstandardAttribute` which can contain any type of data. The standard attributes are constrained to have specific names. There may be from one to many occurrences each with a unique name within the `Step` named identified file.

Attribute

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Attribute	ABSTRACT	A characteristic that may be any of a group of enumerated string description or a unique string for a condition not addressed by the standard attributes.	0-n

8.2.3.2 PadStack

The `PadStack` element consists of multiple padstacks taken from the CAD system and is intended to preserve the data from the layout system. The information noted pertain to the `CadProperty` of which the padstack is a part. The relationship is identified by the `CadProperty` unique name and is the original design file from the CAD system. The data becomes redundant when the individual layered features are defined and is then for reference only.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
PadStack	PadStackType	A nested element containing a list of all the `PadStack` configurations taken from the CAD file as a descriptions of the original design of the board or panel and their application to the electronic product. The data is redundant when layered fabrication is defined in the file, and therefore is for reference only.	0-n
net	qualifiedNameType	The name attached to the electrical description of the conductive hole pattern.	0-1
LayerHole	layerHoleType	The hole description of the padstack including all its attributes.	0-1
LayerPad	layerPadType	A nested element defining the pad(s) that the hole traverses indicating location and layer reference for different pad sizes.	0-n

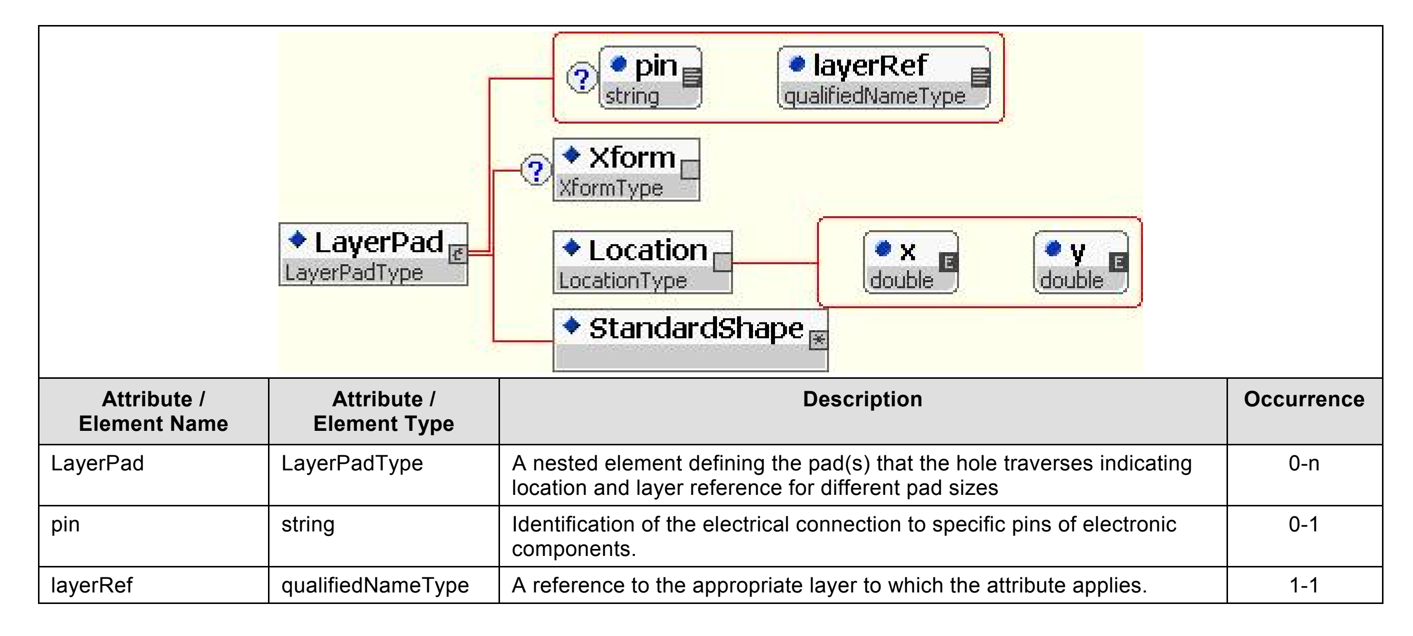
8.2.3.2.1 LayerHole

The `LayerHole` element associated with a padstack identifies the distance through which the hole transcends as a span between individual layers.

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LayerHole	LayerHoleType	The hole description of the padstack including all its attributes.	0-1
name	qualifiedNameType	A unique identification of a particular hole.	1-1
diameter	nonNegativeDouble Type	The nominal diameter of the hole in the as-finished state.	1-1
platingStatus	platingStatusType	The type of hole defined as an enumerated string indicating PLATED | NONPLATED | VIA.	1-1
plusTol	nonNegativeDouble Type	The plus tolerance that defines the variation permitted from the nominal hole-diameter.	1-1
minusTol	nonNegativeDouble Type	The minus tolerance that defines the variation permitted fromthe nominal hole-diameter.	1-1
x	double	The x-location of the hole.	1-1
y	double	The y-location of the hole.	1-1
Span	SpanType	A nested element where the field may be added to layers of type drill and route that are either buried or blind. In such a case, it represents the start and end board layers between which drilling/routing is done. If the drill layer is going through the board, it is required not to be included in a span subsection.	1-1

8.2.3.2.2 LayerPad

The `LayerPad` element is a group of specific graphic features that become part of the padstack with a description of the pin to which the padstack applies and the layer on which the individual pad is located.

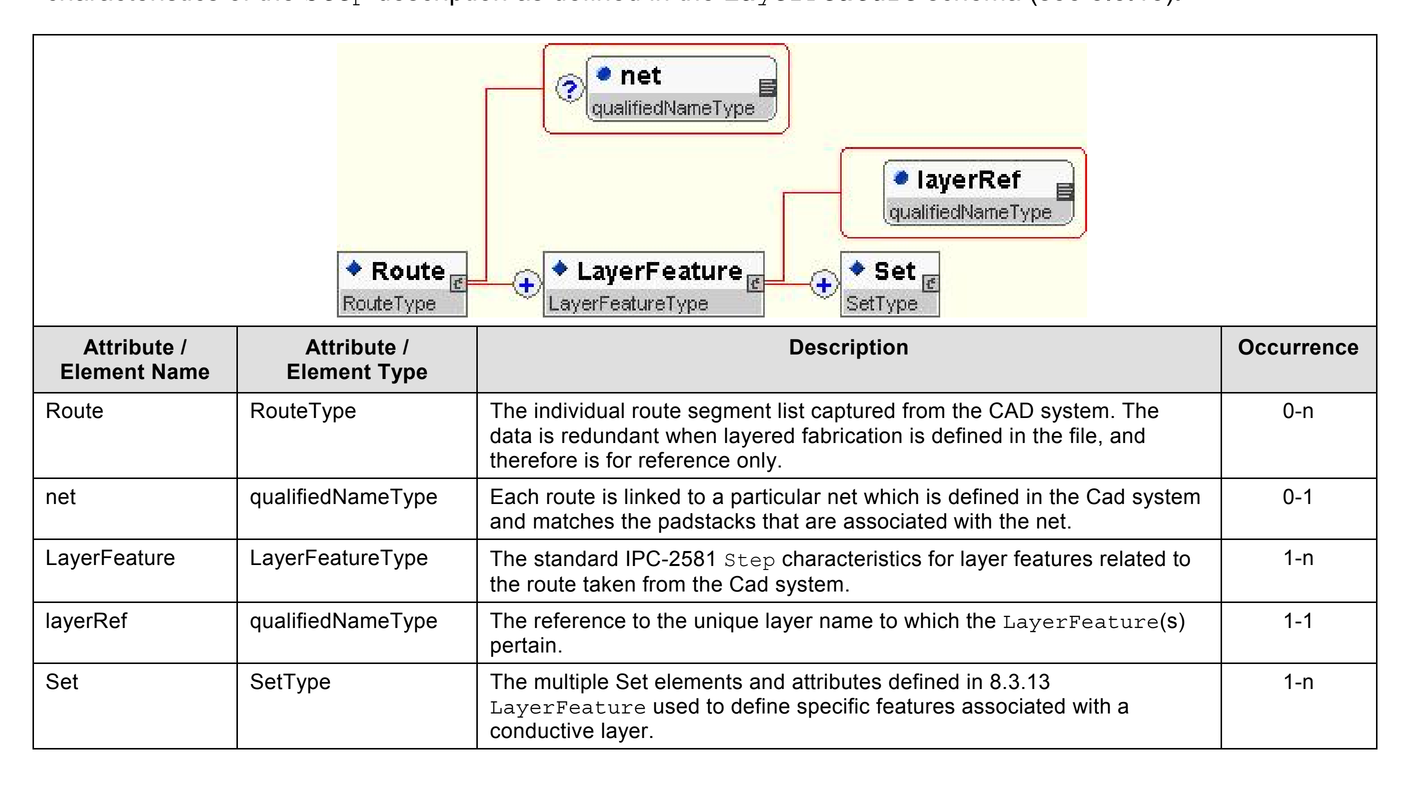


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LayerPad	LayerPadType	A nested element defining the pad(s) that the hole traverses indicating location and layer reference for different pad sizes	0-n
pin	string	Identification of the electrical connection to specific pins of electronic components.	0-1
layerRef	qualifiedNameType	A reference to the appropriate layer to which the attribute applies.	1-1

Xform	XformType	An element that provides the ability to reset the point of origin of a predefined pad that can be scaled, mirror imaged or rotated. See paragraph 3.3	0-1
Location	LocationType	The location of the image defined by the `StandardShape` or a pre-defined `StandardShape` of the pad. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location of the pad.	1-1
y	double	The y coordinate of the location of the pad.	1-1
StandardShape	ABSTRACT	A substitution group that may call for any `StandardPrimitive`, instantiated by describing their unique features or by referencing a predefined primitive contained in the `DictionaryStandard`.	1-1

8.2.3.3 Route

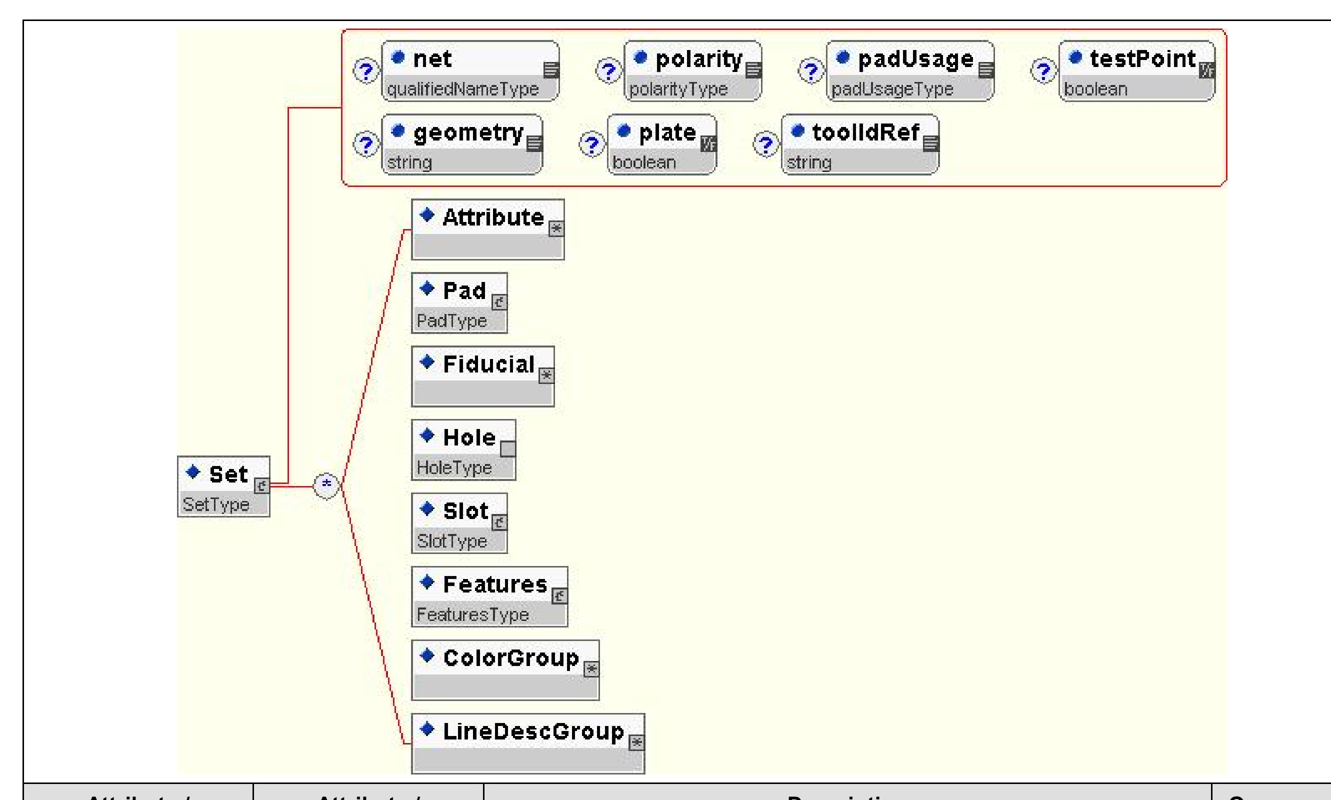
The `Route` element consists of multiple routes taken from the CAD system and is intended to preserve the data from the layout system. Each `Route` is referenced to a particular `Net` and a layer on which the route or net occurs as taken from the CAD system. The data becomes redundant when the individual layered features are defined and is then for reference only. The `Route` element uses the same characteristics of the `Step` description as defined in the `LayerFeature` schema (see 8.3.13).



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Route	RouteType	The individual route segment list captured from the CAD system. The data is redundant when layered fabrication is defined in the file, and therefore is for reference only.	0-n
net	qualifiedNameType	Each route is linked to a particular net which is defined in the Cad system and matches the padstacks that are associated with the net.	0-1
LayerFeature	LayerFeatureType	The standard IPC-2581 `Step` characteristics for layer features related to the route taken from the Cad system.	1-n
layerRef	qualifiedNameType	The reference to the unique layer name to which the `LayerFeature`(s) pertain.	1-1
Set	SetType	The multiple Set elements and attributes defined in 8.3.13 `LayerFeature` used to define specific features associated with a conductive layer.	1-n

8.2.3.3.1 Set

A specific set of graphical descriptions for a particular set of graphical shapes. These shapes are applied defining the conductive pattern of the printed board.

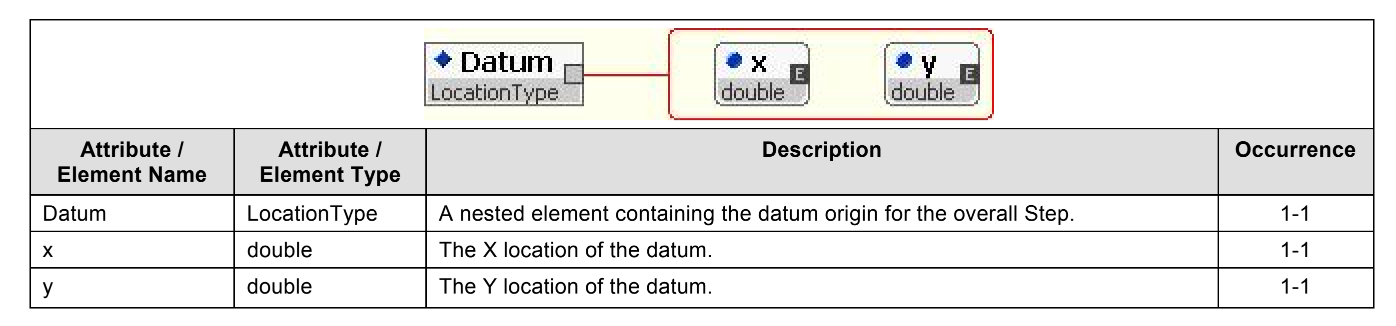


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Set	SetType	The multiple Set elements and attributes defined in 8.3.1 used to define specific features associated with a conductive layer.	1-n
net	qualifiedNameType	The electrical relationship of any feature, through the name of the `PhyNet`, when the `Set` feature has conductivity checked in the `PhyNetPoint` descriptions. This attribute is left blank if the `Set` descriptions are for other than printed board fabrication or assembly conductivity.	0-1
polarity	polarityType	`Polarity` indicates whether the information described in the `Set` is POSITIVE | NEGATIVE. A NEGATIVE connotation can be used to describe the removal of a dark field to the specific dimensions described for another attribute. Thus, a surface that contains islands may have the islands described in a negative format.	0-1
padUsage	padUsageType	An indication as to the usage of any pad that becomes a part of the `LayerFeature Set`. The descriptions are enumerated strings and must be one of the following: TOE | VIA | GLOBAL_FIDUCIAL | LOCAL_FIDUCIAL | TOOLING_HOLE | NONE.	0-1
testPoint	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE indicates that the feature is a candidate for a test point used for either in-circuit or functional testing. FALSE indicates that it is not.	0-1
geometry	string	An identification to describe the overall geometry of the features contained in the `Set` and their particular application to the electronic product.	0-1
plate	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE indicates that the feature is plated in a secondary operation . FALSE indicates that it is not.	0-1

toolRef	string	A reference to the DrillTool identification (id) defined in the DrillTool instance of the Layer section. This feature is used to associate the drillSize with features that are part of the Set.	0-1
Attribute	ABSTRACT	A substitution group that may be any of a group of enumerated string descriptions or a unique string for a condition not addressed by the standard attributes. The Attribute is associated with the LayerFeature Set.	0-n
Pad	PadType	A series of pads that are associated with the LayerFeature Set.	0-n
Fiducial	ABSTRACT	A substitution that consists of four elements that may be used to replace the fiducial element. When the Fiducial element is substituted it **shall** be by a Global, Local, BadBoardMark, or GoodPanelMark.	0-n
Hole	HoleType	A series of holes associated with the LayerFeature Set.	0-n
Slot	SlotType	A series of slots associated with the LayerFeature Set.	0-n
Features	FeaturesType	An embedded element that defines a substitution group of any predefined StandardShape or UserShape that may be instantiated as a part of the LayerFeature Set.	0-n
ColorGroup	ABSTRACT	A substitution group that permits assigning a particular color through instantiating the three basic colors or by providing a reference to a predefined Color in DictionaryColor.	0-n
LineDescGroup	ABSTRACT	A substitution group that specifies the LineWidth and LineEnd characteristics of a Feature that requires that description. If a predefined feature is instantiated the presents of a LineDescGroup will override the previously defined LineDesc.	0-n

8.2.3.4 Datum

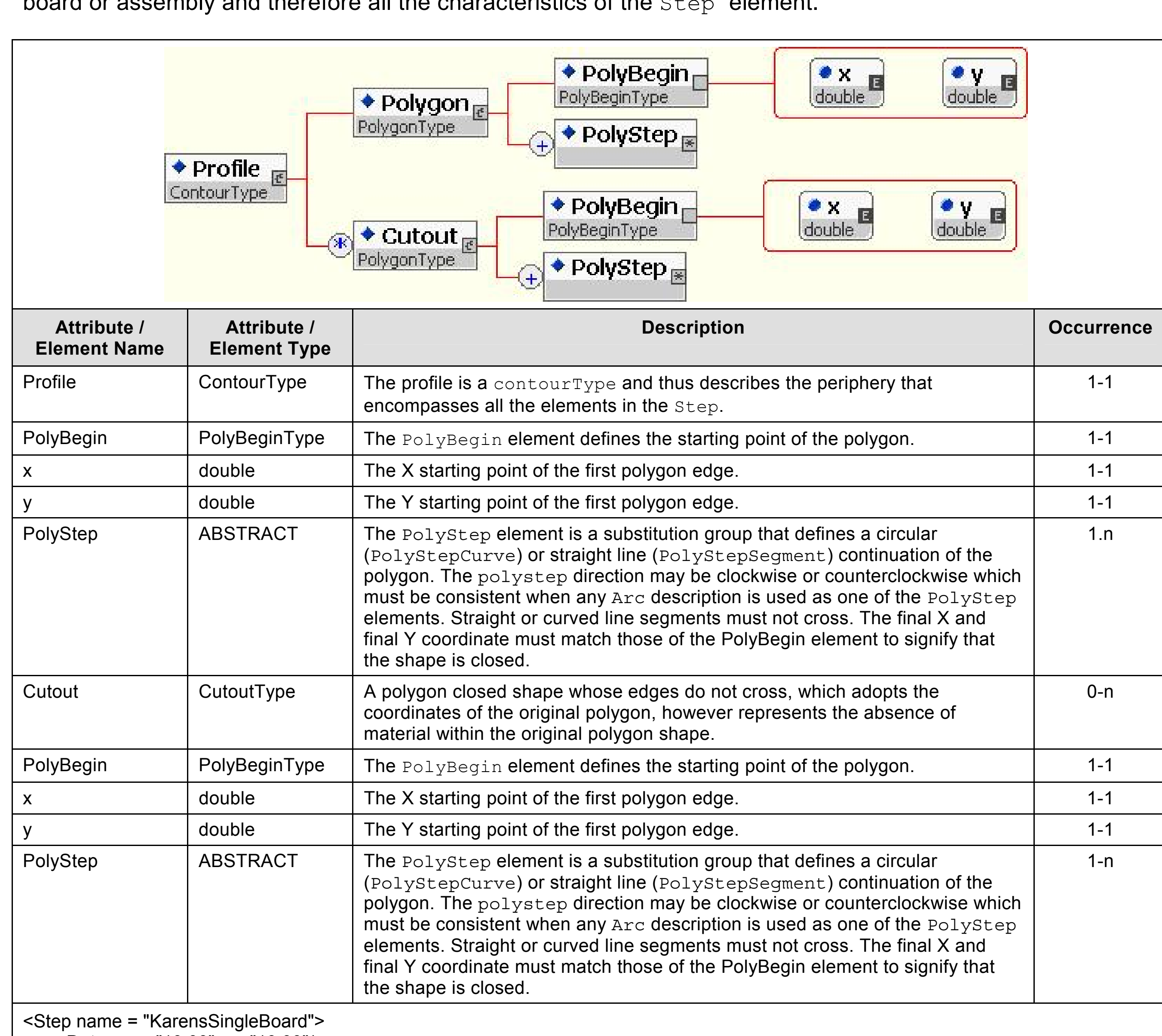
The Datum element of the Step schema (StepType/Datum) defines the location of the point of origin for the individual Step file. The unique name of the Step helps to associate the datum between boards and panels or pallets.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Datum	LocationType	A nested element containing the datum origin for the overall Step.	1-1
x	double	The X location of the datum.	1-1
y	double	The Y location of the datum.	1-1

8.2.3.5 Profile

The `Profile` element of the `Step` schema (`StepTypeProfile`) defines the exact periphery of the board or assembly and therefore all the characteristics of the `Step` element.



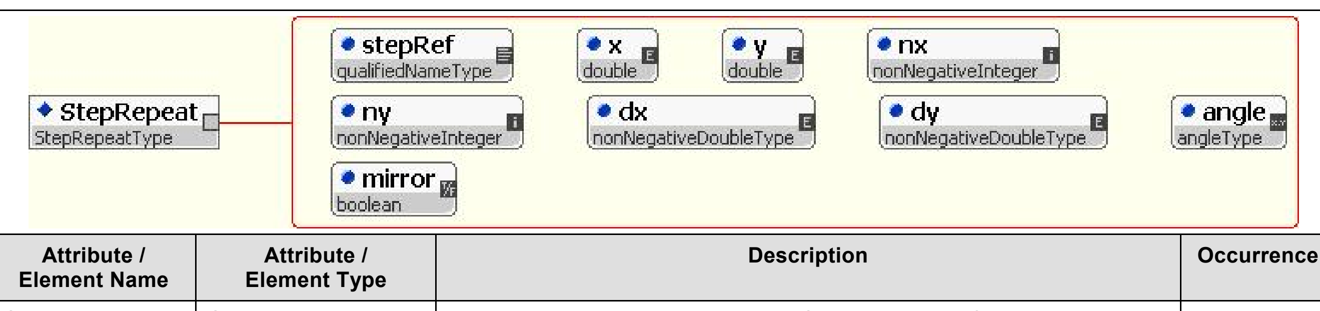
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Profile	ContourType	The profile is a `contourType` and thus describes the periphery that encompasses all the elements in the `Step`.	1-1
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1.n
Cutout	CutoutType	A polygon closed shape whose edges do not cross, which adopts the coordinates of the original polygon, however represents the absence of material within the original polygon shape.	0-n
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1-n

```
<Step name = "KarensSingleBoard">
    <Datum x = "10.00" y = "10.00"/>
      <Profile>
        <Polygon>
          <PolyBegin x = "0.00" y = "10.00"/>
          <PolyStepSegment x = "0.00" y = "90.00"/>
          <PolyStepCurve x = "10.00" y = "100.00" centerX = "10.00" centerY = "90.00" clockwise = "TRUE"/>
          <PolyStepSegment x = "200.00" y = "100.00"/>
          <PolyStepSegment x = "200.00" y = "50.00"/>
          <PolyStepSegment x = "150.00" y = "50.00"/>
          <PolyStepSegment x = "150.00" y = "0.00"/>
          <PolyStepSegment x = "10.00" y = "0.00"/>
          <PolyStepCurve x = "0.00" y = "10.00" centerX = "10.00" centerY = "10.00" clockwise = "TRUE"/>
        </Polygon>
      </Profile>
  </Step>
```

8.2.3.6 StepRepeat

The `StepRepeat` elements provides information for steps representing panels or assembly pallets. Coupons may also use this feature to step the coupon description on the borders of the panel. The layer descriptions of any `Board` and `Coupon` combined in a `Panel` description must be of the same construction. The attribute stepRef is restricted in the XML schema to the unique name of the `Step` element referenced.

If the features of a `StepRepeat` function become unique due to different characteristics such as one `Step` is at 90 degrees while the next `Step` is at 180 degrees two separate `stepRepeat` elements are required.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
StepRepeat	StepRepeatType	A nested element list containing the Step and Repeat functions that impact the information of the electronic product.	0-n
stepRef	qualifiedNameType	A reference to the step that should be replicated on the panel.	1-1
x	double	The X point of origin where the first step should be placed in relationship to the datum. This may be coincident or may be offset from the datum of the particular step.	1-1
y	double	The Y point of origin where the first step should be placed in relationship to the datum. This may be coincident or may be offset from the datum of the particular step.	1-1
nx	nonNegativeInteger	The number of times that the referenced step should be repeated in the X direction.	1-1
ny	nonNegativeInteger	The number of times that the referenced step should be repeated in the Y direction.	1-1
dx	nonNegativeDouble Type	The dimensional distance in the positive X direction as a step from the first position point of origin (not necessarily from the datum).	1-1
dy	nonNegativeDouble Type	The dimensional distance in the positive Y direction as a step from the first position point of origin (not necessarily from the datum).	1-1
angle	angleType	A unique angle to allow rotation of the `StepRepeat` image description where “0°” is as defined with the angle descriptions being counterclockwise (i.e., 45° 90°) from the horizontal zero angle.	1-1
mirror	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the image is mirrored; FALSE indicates that it is not.	1-1

```
<Step name = "KarensAssemblyPanel">
    <Datum x = "0.00" y = "0.00"/>
        <Profile>
            <Polygon>
                <PolyBegin x = "0.00" y = "0.00"/>
                <PolyStepSegment x = "0.00" y = "427.00"/>
                <PolyStepSegment x = "260.00" y = "427.00"/>
                <PolyStepSegment x = "260.00" y = "0.00"/>
                <PolyStepSegment x = "0.00" y = "0.00"/>
            </Polygon>
        </Profile>
        <StepRepeat stepRef = "KarensSingleBoard" x = "110.00" y = "20.00" nx = "1" ny = "1" dx = "120.00" dy = "207.00" angle =
                    "90.00" mirror = "FALSE"/>
        <LayerFeature layerRef = "1-Top Signal">
            <Set polarity = "POSITIVE">
            <GlobalFiducial>
                <Location x = "250.00" y = "10.00"/>
                <Circle diameter = "1.00"/>
            </GlobalFiducial>
            <GlobalFiducial>
                <Location x = "250.00" y = "417.00"/>
                <Circle diameter = "1.00"/>
            </GlobalFiducial>
            <GlobalFiducial>
                <Location x = "10.00" y = "10.00"/>
                <Circle diameter = "1.00"/>
            </GlobalFiducial>
            <BadBoardMark>
                <Location x = "190.00" y = "5.00"/>
                <Circle diameter = "1.50"/>
            </BadBoardMark>
            <BadBoardMark>
                <Location x = "70.00" y = "5.00"/>
                <Circle diameter = "1.00"/>
            </BadBoardMark>
            <BadBoardMark>
                <Location x = "190.00" y = "213.00"/>
                <Circle diameter = "1.00"/>
            </BadBoardMark>
            <BadBoardMark>
                <Location x = "70.00" y = "213.00"/>
                <Circle diameter = "1.00"/>
            </BadBoardMark>
            <GoodPanelMark>
                <Location x = "250.00" y = "213.00"/>
                <Donut shape = "ROUND" outerDiameter = "1.50" innerDiameter = "0.80"/>
            </GoodPanelMark>
        </Set>
    </LayerFeature>
</Step>
```


The following are examples of the step and repeat functions

The following are 6 Panelization use cases that the IPC-258* series must consider in its output. The number in the dark green area refers to a Design (in the last example, there are 4 unique Designs placed within a Panel).

8.2.3.6.1 Single

A single Design is placed in a Panel.

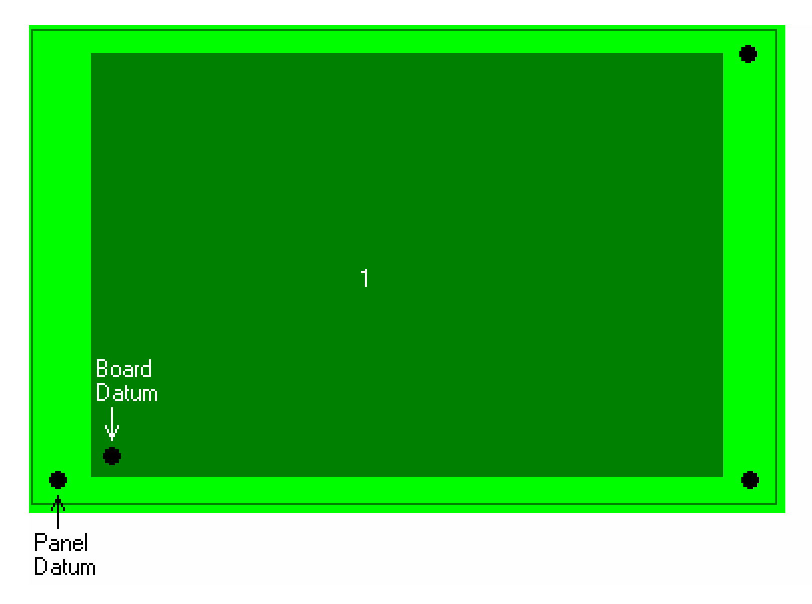


Figure 8 Single Design within a Panel

Requires one StepRepeat element that positions the design on the panel at the appropriate X-Y location.

8.2.3.6.2 Single Array

Step and repeat produces a matrix of steps. The size of the matrix is nx+1 in the x direction, and ny+1 in the y direction.

One Design is placed in the same orientation throughout the panel, based on a single row X column matrix.

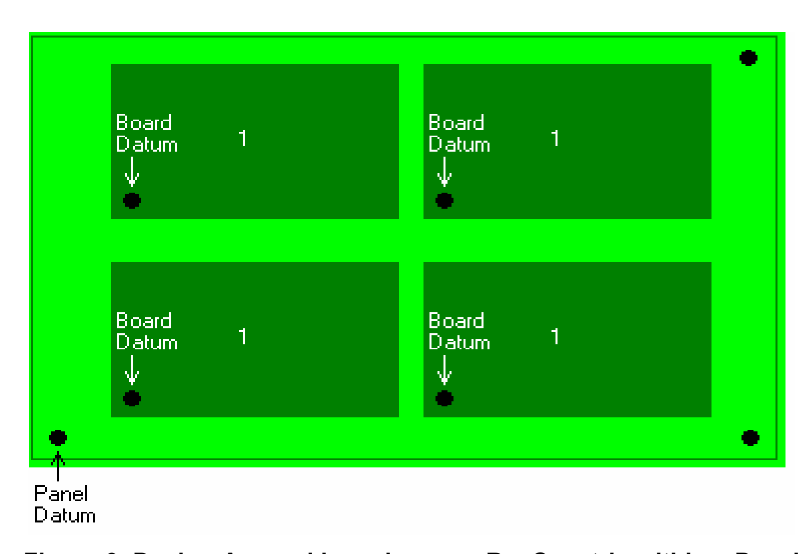


Figure 9 Design Arrayed based on one R x C matrix within a Panel

Requires one StepRepeat element that positions the design on the panel at the appropriate X-Y location. The design is stepped once in the X direction and once in the Y direction. (The upper right hand corner design is automatically created as part of the X-Y step and repeat matrix.)

8.2.3.6.3 Double Array

A single design, but arrayed in two distinct row X column matrices. This panelization method is to use the maximum area of the PCB fabricator's raw panel stock.

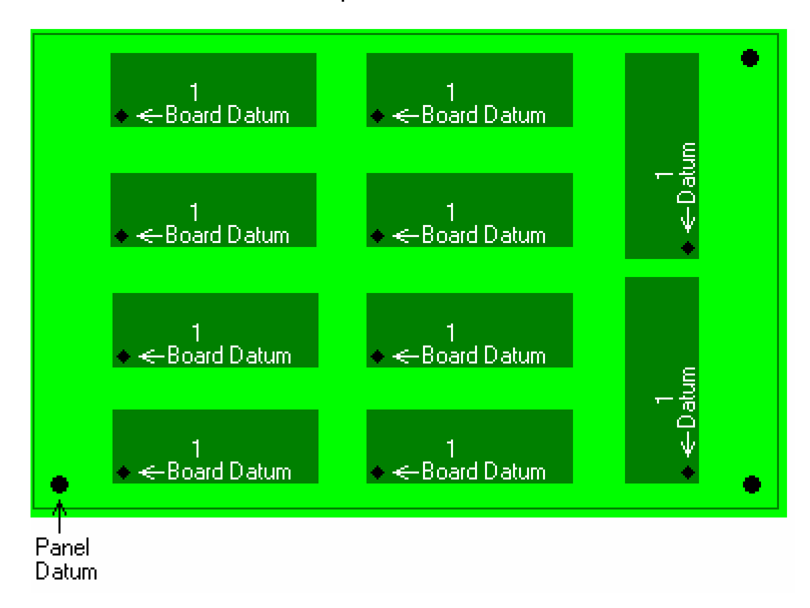


Figure 10 Design Arrayed based on two R x C matrices within a Panel

Requires two StepRepeat elements, one positions the design on the panel at the appropriate X-Y location. The design is then stepped once in the X direction and three times in the Y direction. The second Step Repeat element orients the design on a 90° angle. This new orientation is then positioned on the panel at the appropriate X-Y location, and stepped zero in the X direction and once in the Y direction.

8.2.3.6.4 Tiled

This example is to place a pair of single designs 180° out of phase with each other.

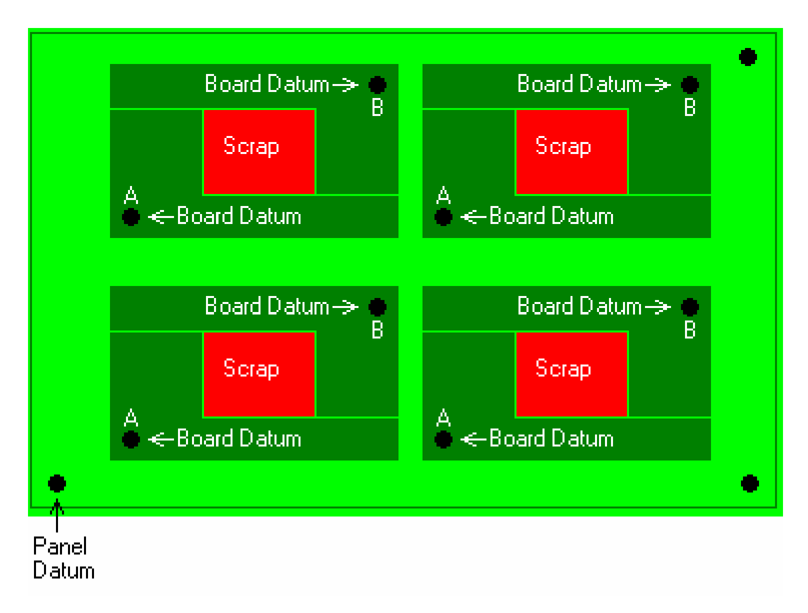


Figure 11 Design tiled as pairs within a Panel

Requires two StepRepeat elements, where one positions the design on the panel at the appropriate X-Y location. This design is then stepped once in the X direction and once in the Y direction. The second Step Repeat element rotates the design 180°, and then positions the new orientation on the panel at the appropriate X-Y location. This reoriented design is then stepped once in the X direction and once in the Y direction. An appropriate X-Y location may be in the lower left portion of the panel with a positive X-Y step or in the upper right corner of the panel with a negative X-Y step.

8.2.3.6.5 Flipped

“Flip” board pairing. This methodology is recent. The most important concern is that the board must be a symmetrical stackup, which means that the layer stackup must be verified to allow this type of panelization.



Figure 12 Design flipped as a pair within a Panel

Requires two StepRepeat elements, one positions the design on the panel at the appropriate X-Y location.. The second Step Repeat element identifies the design as a mirrorImage, which is then positioned on the panel at the appropriate X-Y location. There is no StepRepeat description necessary as the designs are both uniquely positioned.

8.2.3.6.6 Multiple Designs

The most important consideration with placing multiple designs (each number represents a unique design) within one panel is that all designs need to have been created within the same layer stackup. The advantage is that an entire product can be assembled/tested all at once. The disadvantage is that if one board of the panel has a problem (either with part availability or performance), this can lead to several additional scheduling/building/etc. problems as well.

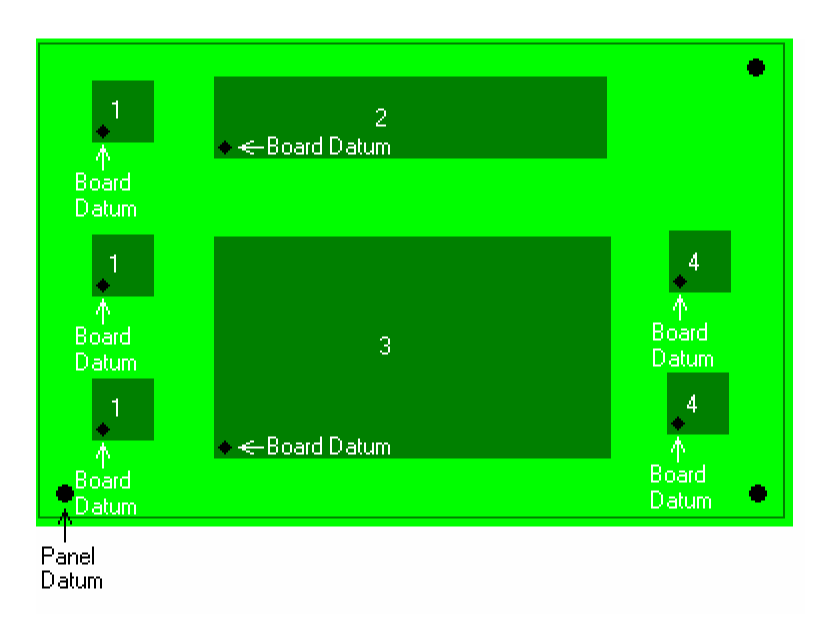


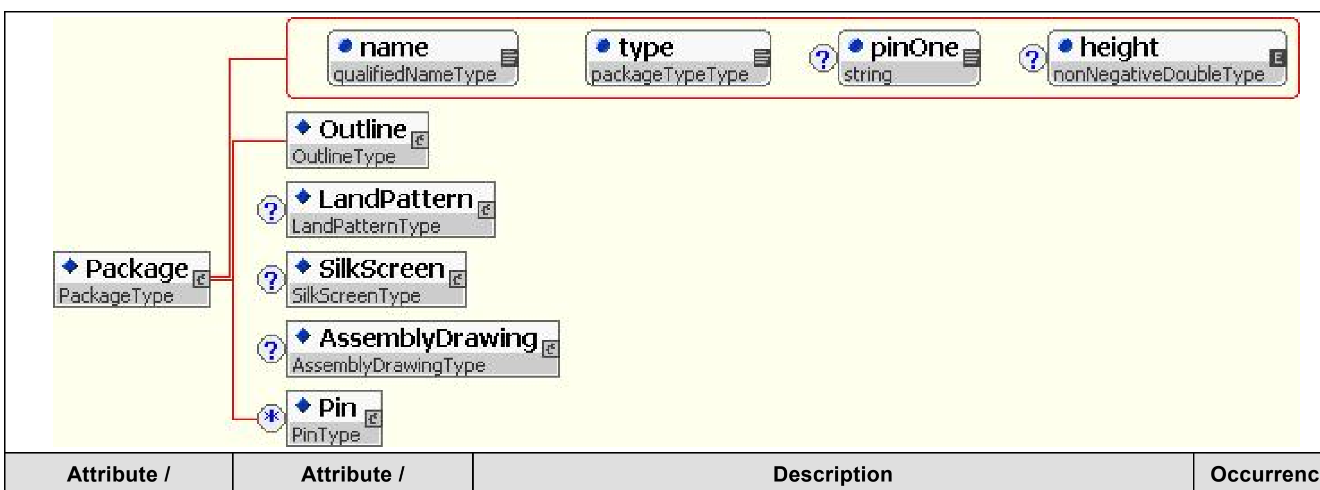
Figure 13 Multiple Designs placed within a Panel

The panel requires four StepRepeat elements. Design 1 is positioned on the panel at the appropriate X-Y location, and is then stepped zero times in the X direction and twice in the Y direction. Design 2 references a different Step and is positioned on the panel at the appropriate X-Y location. Design 3 references a different Step and is positioned on the panel at the appropriate X-Y location. Neither design 2 or 3 requires any stepRepeat information. The fourth Step Repeat element identifies design 4 is also a different Step which is positioned on the panel at the appropriate X-Y location, and stepped zero times in the X direction and once in the Y direction.

See Appendix B for an example of an XML instance file.

8.2.3.7 Package

The `Package` element descriptions define the package shape (`Outline`), library descriptions including land patterns, silk screen information, assembly drawing details, and pin identification. The `Package` element defines all the physical description of all the packages used by the `Component` element inside the `Step`. The names assigned to the package should be consistent with the naming convention established in IPC-7350 series of parts and land pattern descriptions. (See Appendix A)

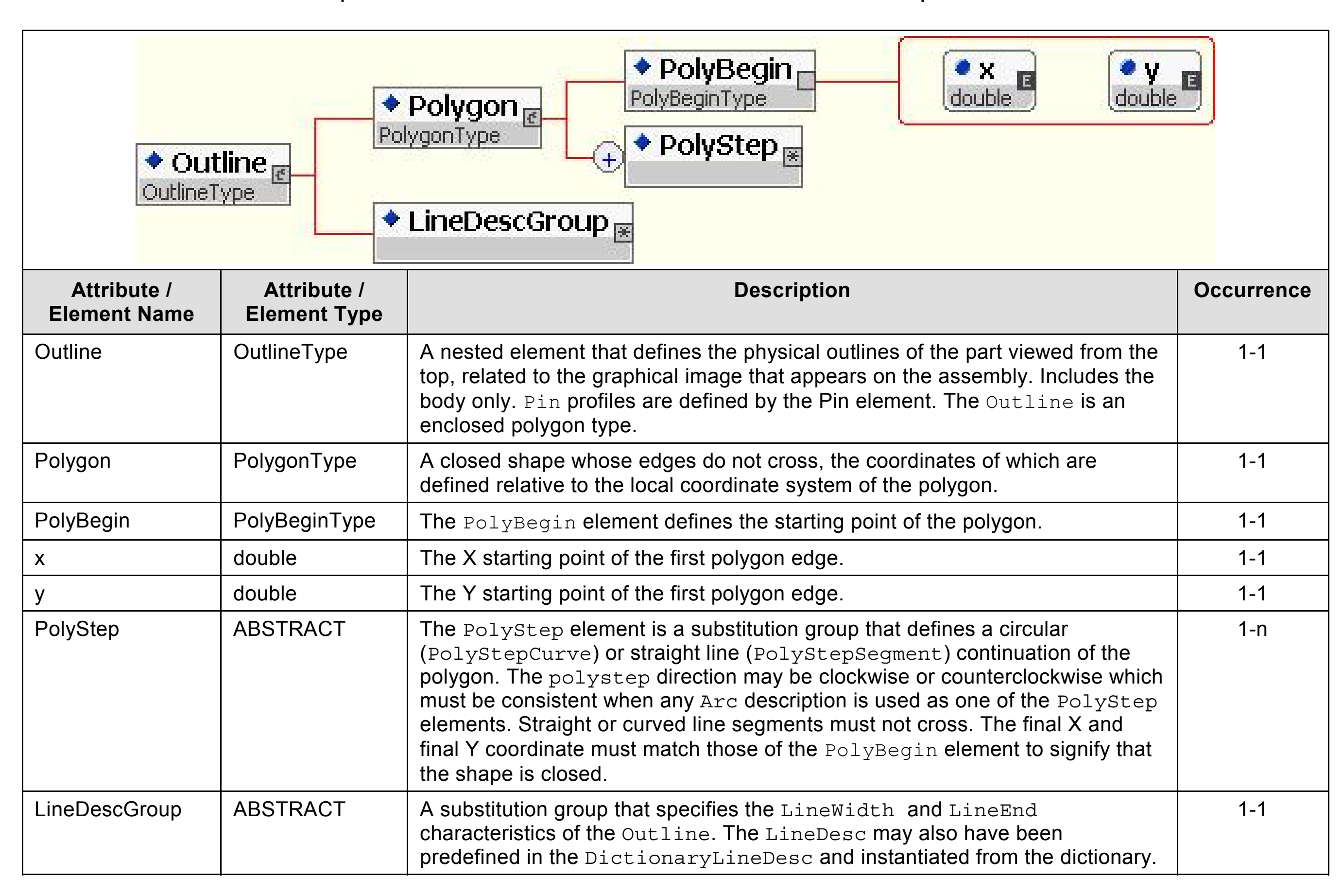


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Package	PackageType	Generic component package descriptions for use by the `Step` file schemas.	0-n
name	qualifiedNameType	A unique name assigned to the physical and graphical description of a part in accordance with the IPC-7351 Naming Convention for Packages and Land Patterns.	1-1
type	PackageTypeType	A specific body construction indicated as an enumerated string using one of the following naming conventions: AXIAL_LEADED | BARE_DIE | CERAMIC_BGA | CERAMIC_DIP | CERAMIC_FLATPACK | CERAMIC_QUAD_FLATPACK | CERAMIC_SIP | CHIP | CHIP_SCALE | CHOKE_SWITCH_SM | COIL | CONNECTOR_SM | CONNECTOR_TH | EMBEDDED | FLIPCHIP | HERMETIC_HYBRED | LEADLESS_CERAMIC_CHIP_CARRIER | MCM | MELF | FINEPITCH_BGA | MOLDED | NETWORK | PGA | PLASTIC_BGA | PLASTIC_CHIP_CARRIER | PLASTIC_DIP | PLASTIC_SIP | POWER_TRANSISTOR | RADIAL_LEADED | RECTANGULAR_QUAD_FLATPACK | RELAY_SM | RELAY_TH | SOD123 | SOIC | SOJ | SOPIC | SOT143 | SOT23 | SOT52 | SOT89 | SQUARE_QUAD_FLATPACK | SSOIC | SWITCH_TH | TANTALUM | TO_TYPE | TRANSFORMER | TRIMPOT_SM | TRIMPOT_TH | OTHER	1-1
pinOne	string	A description of Pin one of the part in accordance with its relationship to the original orientation as stored. Pin one moves with the change in orientation.	0-1
height	double	A description of the component height in terms of the mounting surface to the highest protrusion of the `Package`. The units are in the `Units` set by the `Cadheader`.	0-1
Outline	OutlineType	A nested element that defines the physical outline of the part as seen from the top, related to the graphical image that appears on the assembly. Includes body and pin profiles if applicable. The outline is an enclosed polygon type.	1-1
LandPattern	LandPatternType	A nested element that defines the surface land pattern consisting of Lands in a particular pattern that matches the footprint of the component outline. The point of origin of the `LandPattern` and `Outline` are identical.	0-1

SilkScreen	SilkScreenType	A nested element that defines the symbolization and legend required to be placed on the board for the particular package. Includes location of the reference designator or other `Text`. The point of origin of the image is the same as the origin of the `LandPattern` and `Outline`.	0-1
AssemblyDrawing	AssemblyDrawing Type	A nested element that defines the graphics required for the assembly drawing. The images relate to the component body outline and any text needed. The point of origin for the assembly drawing is the same as the images of the `Outline`, LandPattern, and `SilkScreen` schema.	0-1
Pin	PinType	A nested element that defines the pin relationship of all the pins that are a part of the package style related to the land pattern description.	0-n

8.2.3.7.1 Outline

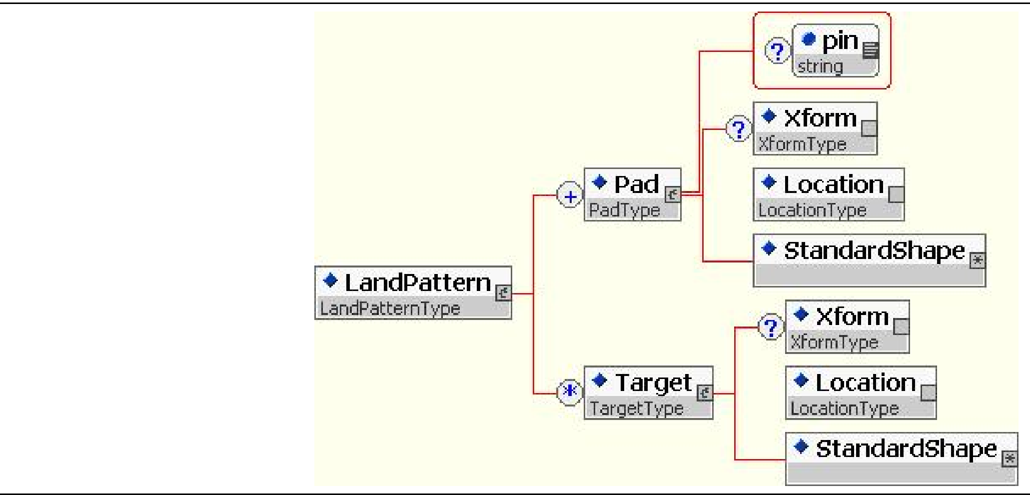
A nested element that defines the physical outlines of the part related to the graphical image that appears on the assembly. The `Outline` includes the body of the part, the `Pin` element and the `Pin` element includes the `Pin` profiles. These are combined to describe the component.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Outline	OutlineType	A nested element that defines the physical outlines of the part viewed from the top, related to the graphical image that appears on the assembly. Includes the body only. `Pin` profiles are defined by the Pin element. The `Outline` is an enclosed polygon type.	1-1
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon.	1-1
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the `PolyBegin` element to signify that the shape is closed.	1-n
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Outline`. The `LineDesc` may also have been predefined in the `DictionaryLineDesc` and instantiated from the dictionary.	1-1

8.2.3.7.2 LandPattern

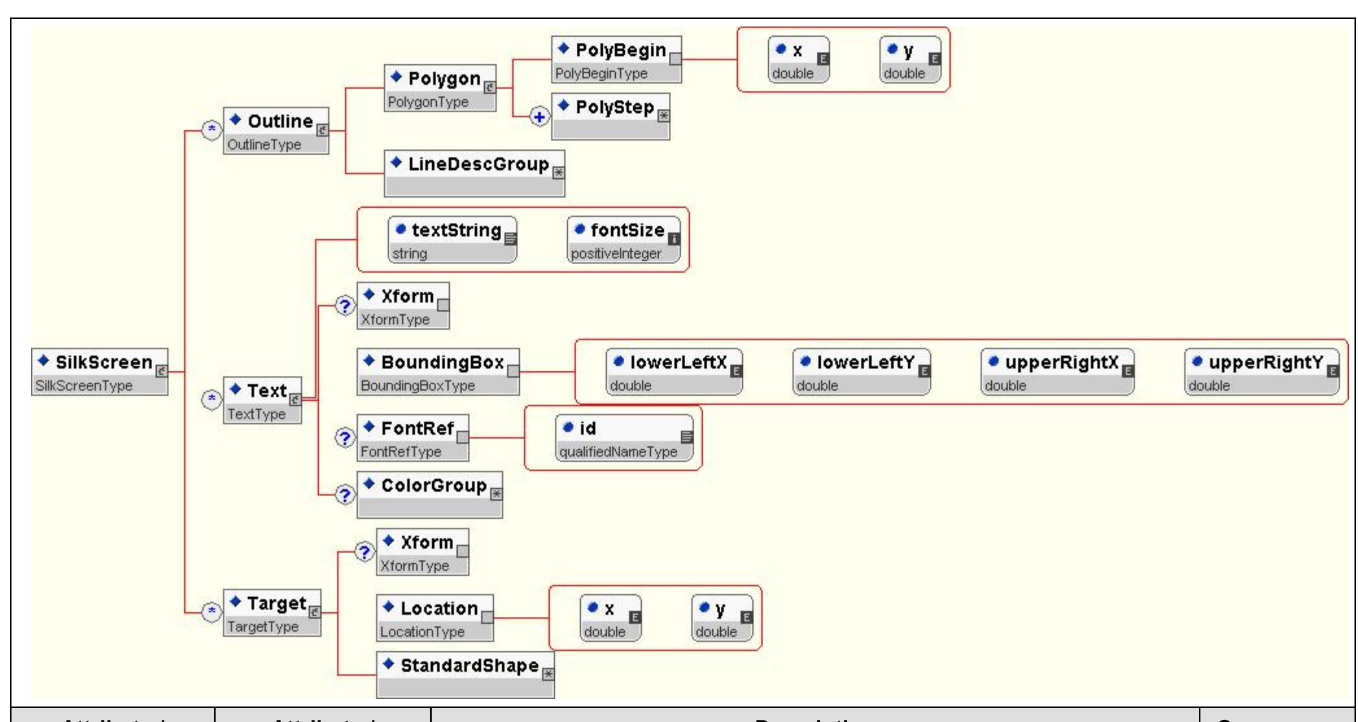
The `LandPattern` element consists of those characteristics that define the pattern to which surface mount components are attached. The embedded elements include both the `Pad` description and the potential for providing a target, usually indicating `pinOne`. Land pattern descriptions should be used wherever a relationship to component pins needs to be established. This information is redundant when layers for component attachment are defined.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LandPattern	LandPatternType	A nested element that defines the surface land pattern consisting of Pads in a particular pattern that matches the footprint of the component.	0-1
Pad	PadType	A nested element defining the pad to be located as part of the land pattern.	1-n
pin	string	A description relating the `Pad` to a specific pin of the component being mounted on the particular land pattern.	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined pad that can be scaled, mirror imaged or rotated. See paragraph 3.3	0-1
Location	LocationType	The location of the image defined by the standard shape or a pre-defined standard shape of the pad. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location of the pad.	1-1
y	double	The y coordinate of the location of the pad.	1-1
StandardShape	ABSTRACT	A substitution group that permits the substitution of any of the `StandardPrimitive` shapes in accordance with their individual descriptions. A predefined `StandardPrimitive` may also be instantiated by its unique “id” when the feature is contained in the DictionaryStandard. When a reference is made to the dictionary predefined primitive the `Units` must match.	1-1
Target	TargetType	A nested element defining the target to be located as part of the land pattern.	0-n
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined target that can be scaled, mirror imaged or rotated. See paragraph 3.3	0-1
Location	LocationType	The location of the image defined by the standard shape or a pre-defined standard shape of the target. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location of the target.	1-1
y	double	The y coordinate of the location of the target.	1-1
StandardShape	ABSTRACT	A substitution group that permits the substitution of any of the `StandardPrimitive` shapes in accordance with their individual descriptions. A predefined `StandardPrimitive` may also be instantiated by its unique “id” when the feature is contained in the `DictionaryStandard`. When a reference is made to the dictionary predefined primitive the `Units` must match.	1-1

8.2.3.7.3 SilkScreen

The `SilkScreen` element defines the symbolization and legend required to be placed on the board for the particular package. The `SilkScreen` descriptions include location of the reference designator or other `Text`. The point of origin of the image is the same as the origin of the `LandPattern` and `Outline`.

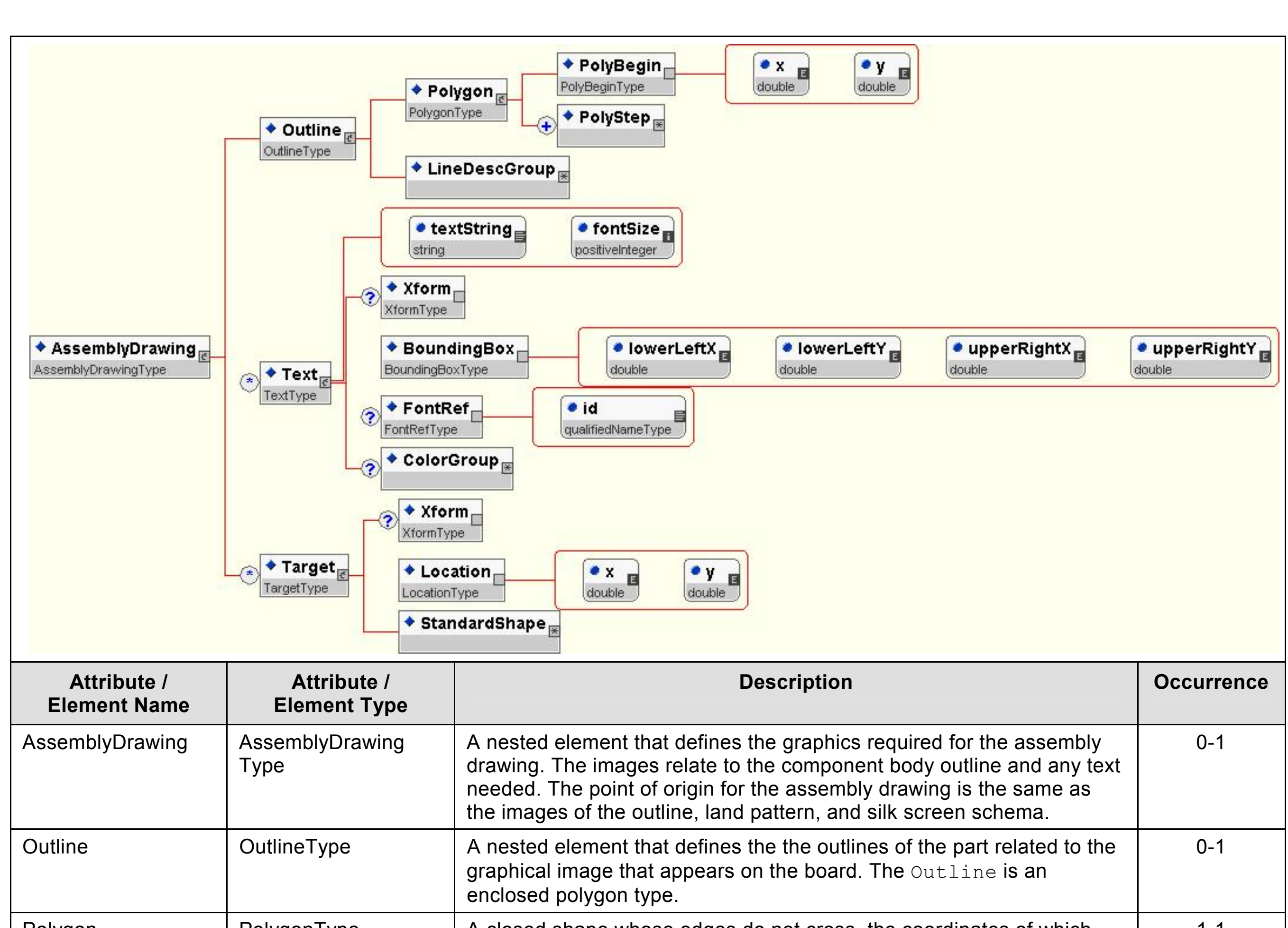


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
SilkScreen	SilkScreenType	A nested element that defines the symbolization and legend required to be placed on the board for the particular package. Includes location of the reference designator or other `Text`. The point of origin of the image is the same as the origin of the `LandPattern` and `Outline`.	0-1
Outline	OutlineType	A nested element that defines the outlines of the part related to the graphical image that appears on the board. The outline is an enclosed polygon type.	0-n
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon.	1-1
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the `PolyBegin` element to signify that the shape is closed.	1-n
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Outline`. The `LineDesc` may also have been predefined in the `DictionaryLineDesc` and instantiated from the dictionary.	1-1
Text	TextType	A nested element that defines the text to be silkscreened onto the surface of the printed board.	0-n

textString	string	The text phrase (case-sensitive) in accordance with the language element of the Header element representing the specific characters to be silkscreened onto the board surface.	1-1
fontSize	positiveInteger	A dimensional characteristic in terms of an integer that defines the font size	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of the text box, then scale, mirror image or rotate the text box after the text box origin has been placed at an X and Y location. See paragraph 3.3	0-1
x	double	The x coordinate of the location of the point of origin (lowerLeftX) of the BoundingBox.	1-1
y	double	The y coordinate of the location of the point of origin (lowerLeftY) of the BoundingBox.	1-1
Boundingbox	BoundingBoxType	A constraining rectangular area (bounding box) that encompasses the entire text string including upper and lower case characters.	1-1
lowerLeftX	double	The lower left hand x dimension of the rectangular area encompassing the text.	1-1
lowerLeftY	double	The lower left hand y dimension of the rectangular area encompassing the text.	1-1
upperRightX	double	The upper right hand x dimension of the the rectangular area encompassing the text.	1-1
upperRightY	double	The upper right hand y dimension of the rectangular area encompassing the text.	1-1
FontRef	FontRefType	An element that is optional to reference a predefined font by its id, if the standard Helvetica font is not being instantiated.	0-1
id	qualifiedName Type	The identification of the FontDef stored in the DictionaryFont.	1-1
ColorGroup	ABSTRACT	An optional substitution group that permits assigning a particular color through instantiating the three basic colors or by providing a reference to a predefined Color in DictionaryColor.	0-1
Target	TargetType	A nested element defining the target to be located as part of the land pattern.	0-n
Xform	XformType	A nested element describing the location and mirroring, rotation or scaling of the StandardShape used to define the Target in order to have it be consistent within the silk screen image description.	0-1
Location	LocationType	The location of the image defined by the standard shape or a pre-defined standard shape of the target. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location of the target.	1-1
y	double	The y coordinate of the location of the target.	1-1
StandardShape	ABSTRACT	A substitution group that permits the substitution of any of the StandardPrimitive shapes in accordance with their individual descriptions. A predefined StandardPrimitive may also be instantiated by its unique “id” when the feature is contained in the DictionaryStandard. When a reference is made to the dictionary predefined primitive the Units must match.	1-1

8.2.3.7.4 AssemblyDrawing

The AssemblyDrawing element reuses the same embedded elements and attributes as defined for the Silkscreen characteristics. The construction schemas are repeated to aid the reader in interpretation of the library structure.

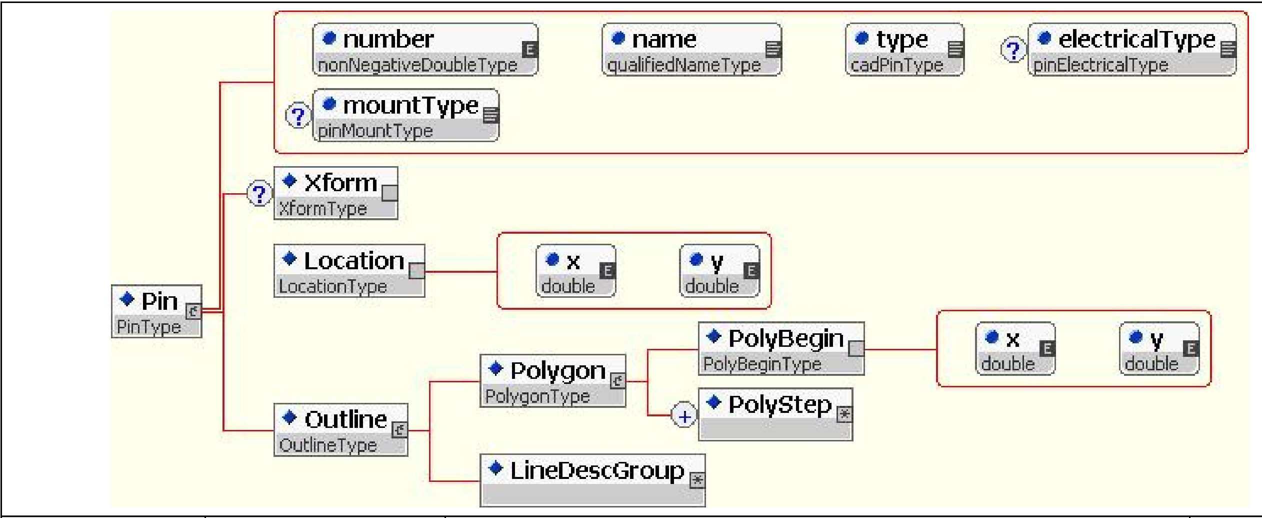


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
AssemblyDrawing	AssemblyDrawing Type	A nested element that defines the graphics required for the assembly drawing. The images relate to the component body outline and any text needed. The point of origin for the assembly drawing is the same as the images of the outline, land pattern, and silk screen schema.	0-1
Outline	OutlineType	A nested element that defines the the outlines of the part related to the graphical image that appears on the board. The `Outline` is an enclosed polygon type.	0-1
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon	1-1
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge	1-1
PolyStep	ABSTRACT	The `PolyStep` element is a substitution group that defines a circular (`PolyStepCurve`) or straight line (`PolyStepSegment`) continuation of the polygon. The `polystep` direction may be clockwise or counterclockwise which must be consistent when any `Arc` description is used as one of the `PolyStep` elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the `PolyBegin` element to signify that the shape is closed.	1-n
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of the `Outline`. The `LineDesc` may also have been predefined in the `DictionaryLineDesc` and instantiated from the dictionary.	1-1
Text	TextType	A nested element that defines the text to be silkscreened onto the surface of the printed board.	0-n
textString	string	The text phrase (case-sensitive) in accordance with the language element of the Header element representing the specific characters to be silkscreened onto the board surface.	1-1
fontSize	positiveInteger	A dimensional characteristic in terms of an integer that defines the font size	1-1
Xform	XformType	An element that provides the ability to reset the point of origin of the text box, then scale, mirror image or rotate the text box after the text box origin has been placed at an X and Y location. See paragraph 3.3	0-1

x	double	The x coordinate of the location of the point of origin (lowerLeftX) of the BoundingBox.	1-1
y	double	The y coordinate of the location of the point of origin (lowerLeftY) of the BoundingBox.	1-1
Boundingbox	BoundingBoxType	A constraining rectangular area (bounding box) that encompasses the entire text string including upper and lower case characters.	1-1
lowerLeftX	double	The lower left hand x dimension of the rectangular area encompassing the text.	1-1
lowerLeftY	double	The lower left hand y dimension of the rectangular area encompassing the text.	1-1
UpperRightX	double	The upper right hand x dimension of the the rectangular area encompassing the text.	1-1
UpperRightY	double	The upper right hand y dimension of the rectangular area encompassing the text.	1-1
FontRef	FontRefType	An element that is optional to reference a predefined font by its id, if the standard Helvetica font is not being instantiated.	0-1
id	qualifiedNameType	The identification of the FontDef stored in the DictionaryFont .	1-1
ColorGroup	ABSTRACT	An optional substitution group that permits assigning a particular color through instantiating the three basic colors or by providing a reference to a predefined Color in DictionaryColor.	0-1
Target	TargetType	A nested element defining the target to be located as part of the land pattern.	0-n
Xform	XformType	A nested element describing the location and mirroring, rotation or scaling of the StandardShape used to define the Target in order to have it be consistent within the AssemblyDrawing description.	0-1
Location	LocationType	The location of the image defined by the standard shape or a pre-defined standard shape of the pad. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate of the location of the target.	1-1
y	double	The y coordinate of the location of the target.	1-1
StandardShape	ABSTRACT	A substitution group that permits the substitution of any of the StandardPrimitive shapes in accordance with their individual descriptions. A predefined StandardPrimitive may also be instantiated by its unique “id” when the feature is contained in the DictionaryStandard. When a reference is made to the dictionary predefined primitive the Units must match.	1-1

8.2.3.7.5 Pin

The Pin element represents a set of Pin characteristics that are attached to each component package. Each Pin has a number, name, type, electricalType and mountType. Each Pin also contains its relative location and outline.

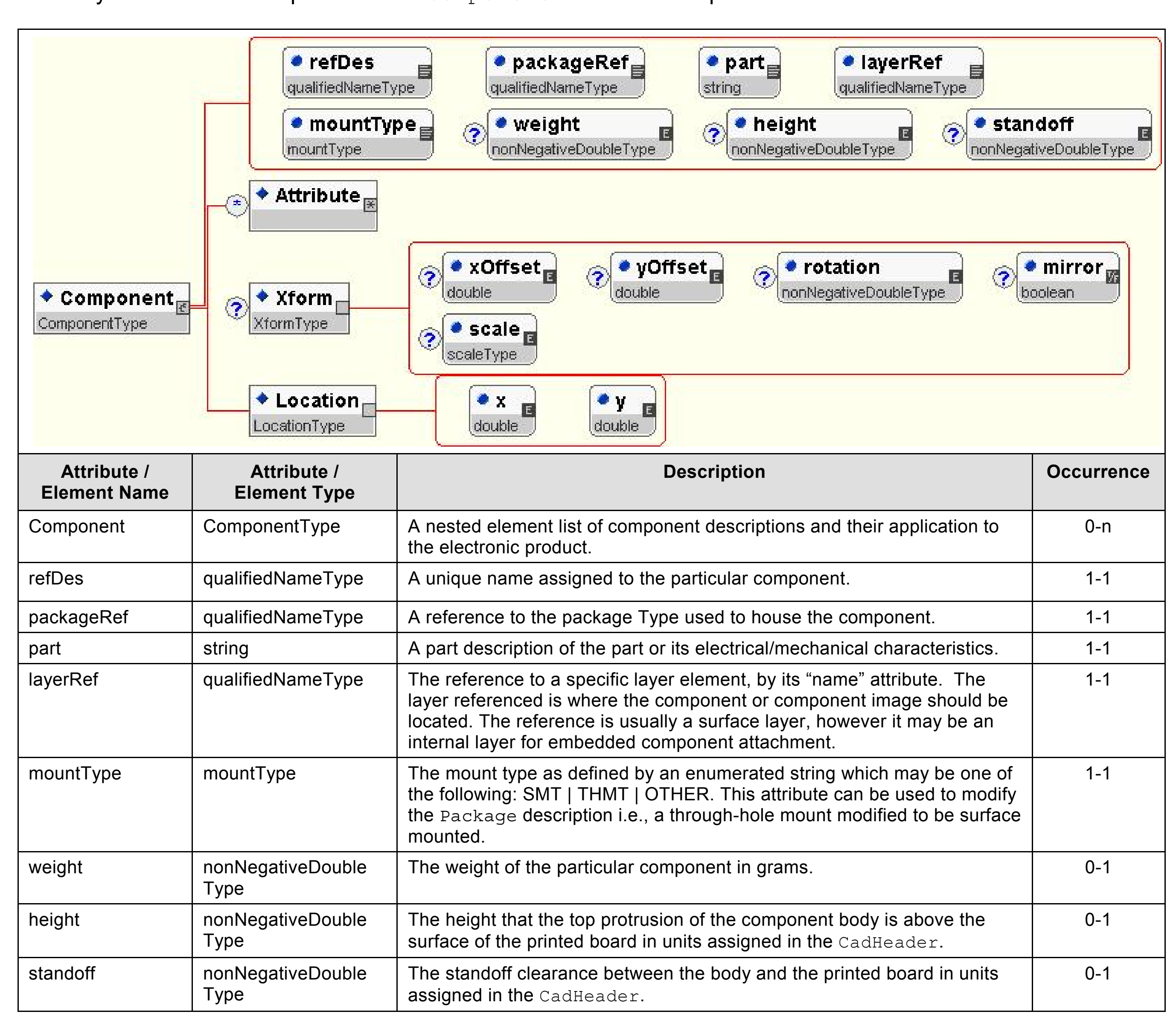


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Pin	PinType	A nested element that defines the pin relationship of all the pins that are a part of the package style related to the land pattern description.	0-n
number	nonNegativeDouble Type	A specific number for the Pin being described. The number is usually an integer, however may require more granularity thus the type is identified as a `nonNegativeDouble`.	1-1
name	qualifiedNameType	A unique name assigned by the user to describe the Pin at a particular location.	1-1
type	cadPinType	An enumerated string that defines the type of Pin as being one of the following: THRU | BLIND | SURFACE.	1-1
electricalType	pinElectricalType	The electrical type enumerated string that defines the Pin as one of three possible conditions. These are: ELECTRICAL | MECHANICAL | UNDEFINED.	0-1
mountType	pinMountType	An enumerated string that defines the mounting characteristics of the Pins and may be any one of the following: SURFACE_MOUNT_PIN | SURFACE_MOUNT_PAD | THROUGH_HOLE_PIN | THROUGH_HOLE_HOLE | PRESSFIT | NONBOARD | HOLE | UNDEFINED	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of the graphic outline pin shape, then scale, mirror image or rotate the shape it has been placed at an X and Y location. See paragraph 3.3	0-1
Location	LocationType	The location of the image defined by the pin shape or a pre-defined standard shape of the `Pin`. The image may have been reorientated by the Xform.	1-1
x	double	The X location of the `Pin` defined by its centroid.	1-1
y	double	The Y location of the `Pin` defined by its centroid.	1-1
Outline	OutlineType	A nested element that defines the the outlines of the part related to the graphical image that appears on the board. The `Outline` is an enclosed polygon type.	1-1
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon	1-1
PolyBegin	PolyBeginType	The `PolyBegin` element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge	1-1

PolyStep	ABSTRACT	The PolyStep element is a substitution group that defines a circular (PolyStepCurve) or straight line (PolyStepSegment) continuation of the polygon. The Polystep direction may be clockwise or counterclockwise which must be consistent when any Arc description is used as one of the PolyStep elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1-n
LineDescGroup	ABSTRACT	A substitution group that specifies the LineWidth and LineEnd characteristics of the Outline. The LineDesc may also have been predefined in the DictionaryLineDesc and instantiated from the dictionary.	1-1

8.2.3.8 Component

The Component section contains all the Component elements that were read from the originating CAD system and were captured in the Component element descriptions.

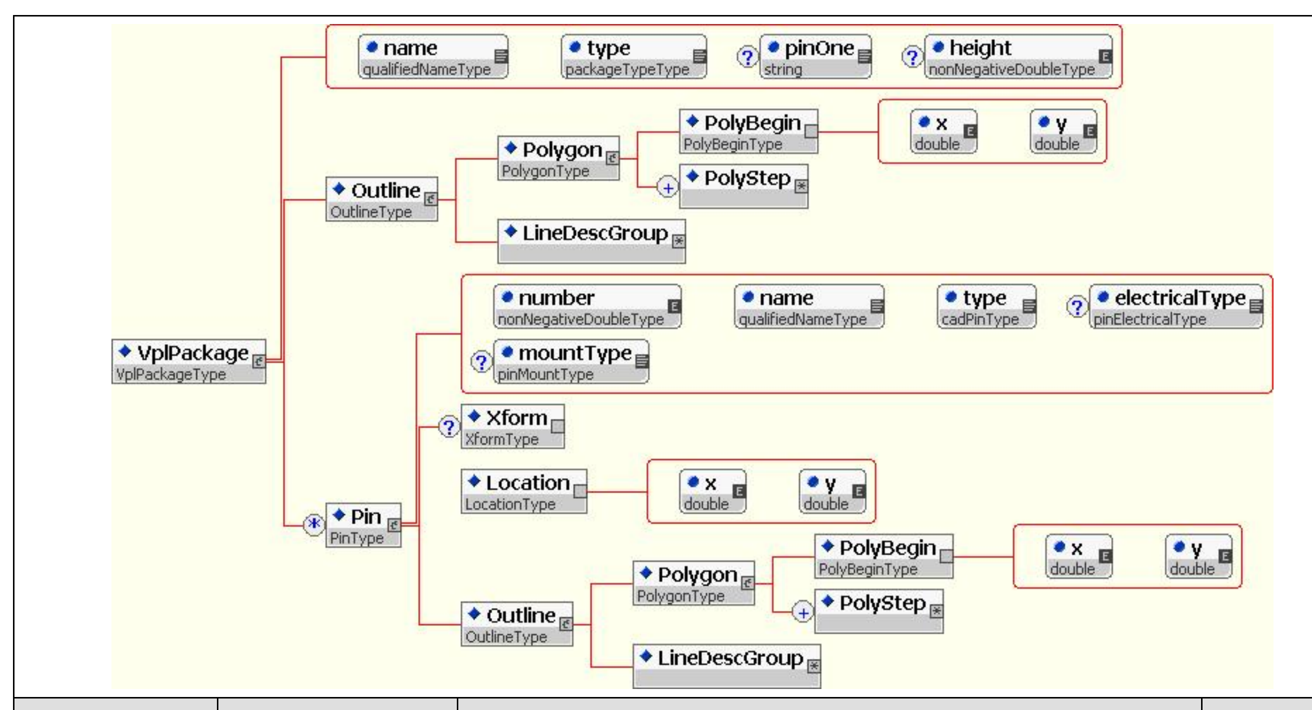


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Component	ComponentType	A nested element list of component descriptions and their application to the electronic product.	0-n
refDes	qualifiedNameType	A unique name assigned to the particular component.	1-1
packageRef	qualifiedNameType	A reference to the package Type used to house the component.	1-1
part	string	A part description of the part or its electrical/mechanical characteristics.	1-1
layerRef	qualifiedNameType	The reference to a specific layer element, by its “name” attribute. The layer referenced is where the component or component image should be located. The reference is usually a surface layer, however it may be an internal layer for embedded component attachment.	1-1
mountType	mountType	The mount type as defined by an enumerated string which may be one of the following: SMT | THMT | OTHER. This attribute can be used to modify the Package description i.e., a through-hole mount modified to be surface mounted.	1-1
weight	nonNegativeDouble Type	The weight of the particular component in grams.	0-1
height	nonNegativeDouble Type	The height that the top protrusion of the component body is above the surface of the printed board in units assigned in the CadHeader.	0-1
standoff	nonNegativeDouble Type	The standoff clearance between the body and the printed board in units assigned in the CadHeader.	0-1

Attribute	ABSTRACT	A substitution group that may be any of a group of enumerated string descriptions or a unique string for a condition not addressed by the standard attributes. The `Attribute` is associated with the `Component` description.	0-n
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined area that can be scaled, mirror imaged or rotated. The image may also by located by the Xform. See paragraph 3.3.	1-1
xOffset	double	The x offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
yOffset	double	The y offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
rotation	nonNegativeDouble Type	Defines the rotation of a shape about the local origin in degrees. Positive rotation is always counter-clockwise as viewed from the board TOP (primary side). Degree accuracy is expressed as a two place decimal i.e., 45.15; 62.34	0-1
mirror	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the image is mirrored; FALSE indicates that it is not.	0-1
scale	scaleType	An attribute that defines a “double” dimension whose minExclusiveValue=0.0 representing the multiplication factor of all x and y dimensions. The scale factor does not apply to angular values.	0-1
Location	LocationType	The location of the component defined by the `packageRef` or a pre-defined standard shape of the `Package`. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate upon which a features’ point-of-origin is located, relative to the point of origin of the product on which a component is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
y	double	The x coordinate upon which a features’ point-of-origin is located, relative to the point of origin of the product on which a component is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1

8.2.3.9 VplPackage

The `VplPackage` element represents information for each component as a new package description that may differ from the original EDA package, thus affecting the shape or the location of the components on the electronic assembly. The details of the `VplPackage` descriptions contain data regarding other possible matching packages for each component. It should be noted that only one package could be set as chosen for a particular component.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
VplPackage	VplPackageType	A nested element list of package types and CAD library descriptions and their application to the electronic product.	0-n
name	qualifiedNameType	A unique name assigned to the physical and graphical description of a part in accordance with the vendor published description criteria.	1-1
type	PackageTypeType	A specific body construction indicated as an enumerated string using one of the following naming conventions. AXIAL_LEADED | BARE_DIE | CERAMIC_BGA | CERAMIC_DIP | CERAMIC_FLATPACK | CERAMIC_QUAD_FLATPACK | CERAMIC_SIP | CHIP | CHIP_SCALE | CHOKE_SWITCH_SM | COIL | CONNECTOR_SM | CONNECTOR_TH | EMBEDDED | FLIPCHIP | HERMETIC_HYBRID | LEADLESS_CERAMIC_CHIP_CARRIER | MCM | MELF | FINEPITCH_BGA | MOLDED | NETWORK | PGA | PLASTIC_BGA | PLASTIC_CHIP_CARRIER | PLASTIC_DIP | PLASTIC_SIP | POWER_TRANSISTOR | RADIAL_LEADED | RECTANGULAR_QUAD_FLATPACK | RELAY_SM | RELAY_TH | SOD123 | SOIC | SOJ | SOPIC | SOT143 | SOT23 | SOT52 | SOT89 | SQUARE_QUAD_FLATPACK | SSOIC | SWITCH_TH | TANTALUM | TO_TYPE | TRANSFORMER | TRIMPOT_SM | TRIMPOT_TH | OTHER	1-1
pinOne	string	A description of Pin one of the part in accordance with its relationship to original orientation as stored. Pin one moves with the change in orientation.	0-1
height	nonNegativeDouble Type	A description of the component height in terms of the mounting surface to the highest protrusion of the VplPackage. The units are in the Units set by the Cadheader.	0-1
Outline	PolygonType	A nested element that defines the physical outlines of the part related to the graphical image that appears on the assembly. Includes body and pin profiles if applicable. The outline is an enclosed polygon type.	1-1
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon.	1-1
PolyBegin	PolyBeginType	The PolyBegin element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge.	1-1

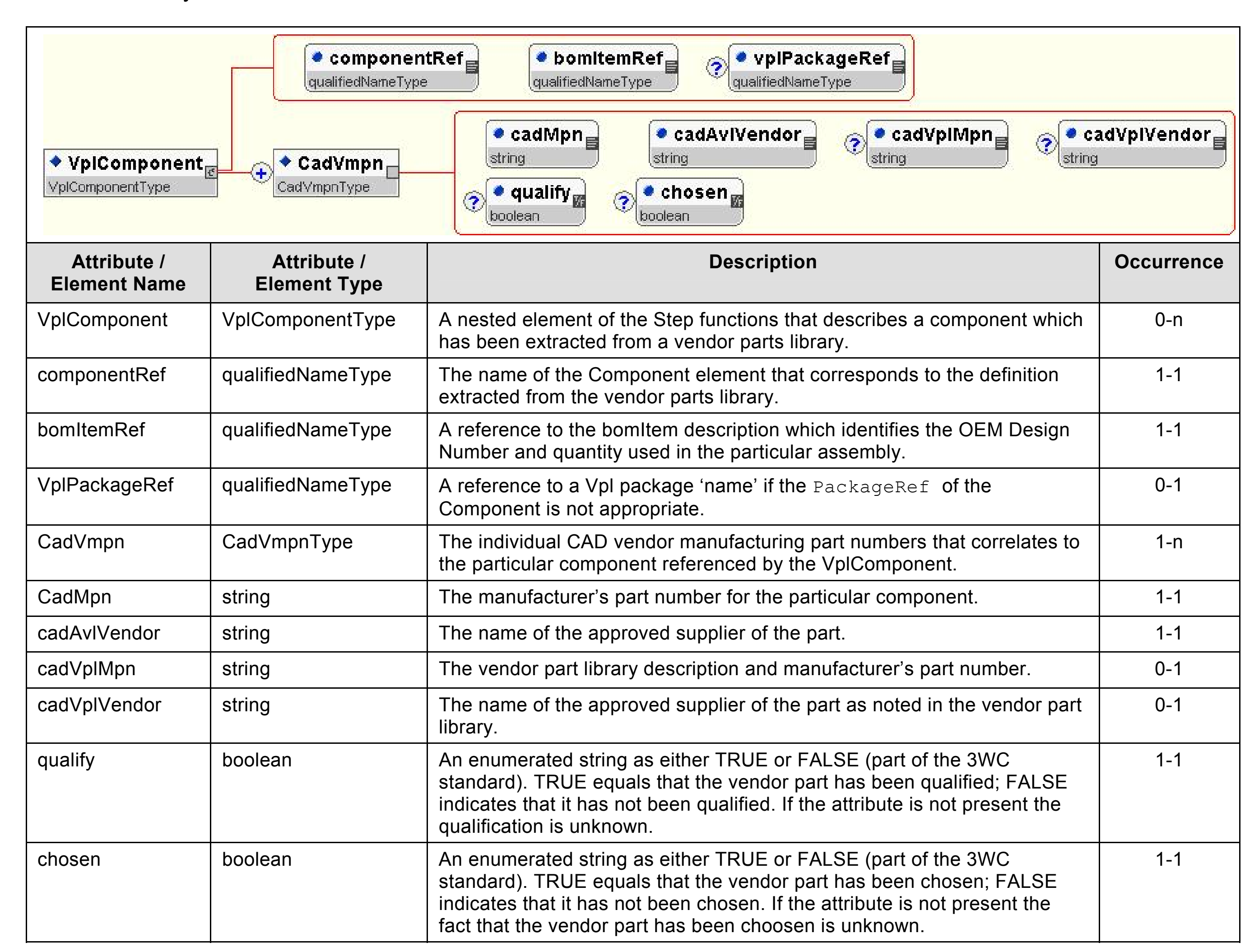
PolyStep	ABSTRACT	The PolyStep element is a substitution group that defines a circular (PolyStepCurve) or straight line (PolyStepSegment) continuation of the polygon. The polystep direction may be clockwise or counterclockwise which must be consistent when any Arc description is used as one of the PolyStep elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1-n
LineDescGroup	ABSTRACT	A substitution group that specifies the LineWidth and LineEnd characteristics of the Outline. The LineDesc may also have been predefined in the DictionaryLineDesc and instantiated from the dictionary.	1-1
Pin	PinType	A nested element that defines the parameters of all the pins that are a part of the VplPackage style.	0-n
number	nonNegativeDouble Type	A specific number for the Pin being described.	1-1
name	qualifiedNameType	A unique name assigned by the user to describe the Pin at a particular location.	1-1
type	cadPinType	An enumerated string that defines the type of Pin as being one of the following: THRU | BLIND | SURFACE.	1-1
electricalType	pinElectricalType	The electrical type enumerated string that defines the Pin as one of three possible conditions. These are: ELECTRICAL | MECHANICAL | UNDEFINED.	0-1
mountType	pinMountType	An enumerated string that defines the mounting characteristics of the Pins and may be any one of the following: SMT | THMT | OTHER.	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of the graphic outline Pin shape, then scale, mirror image or rotate the shape it has been placed at an X and Y location. See paragraph 3.3	0-1
Location	LocationType	The location of the image defined by the Outline or a pre-defined outline shape of the Pin. The image may have been reorientated by the Xform.	1-1
x	double	The X location of the Pin defined by its centroid.	1-1
y	double	The Y location of the Pin defined by its centroid.	1-1
Outline	OutlineType	A nested element that defines the the outlines of the part related to the graphical image that appears on the board. The outline is an enclosed polygon type.	1-1
Polygon	PolygonType	A closed shape whose edges do not cross, the coordinates of which are defined relative to the local coordinate system of the polygon	1-1
PolyBegin	PolyBeginType	The PolyBegin element defines the starting point of the polygon.	1-1
x	double	The X starting point of the first polygon edge.	1-1
y	double	The Y starting point of the first polygon edge	1-1
PolyStep	ABSTRACT	The PolyStep element is a substitution group that defines a circular (PolyStepCurve) or straight line (PolyStepSegment) continuation of the polygon. The polystep direction may be clockwise or counterclockwise which must be consistent when any Arc description is used as one of the PolyStep elements. Straight or curved line segments must not cross. The final X and final Y coordinate must match those of the PolyBegin element to signify that the shape is closed.	1-n
LineDescGroup	ABSTRACT	A substitution group that specifies the LineWidth and LineEnd characteristics of the Outline. The LineDesc may also have been predefined in the DictionaryLineDesc and instantiated from the dictionary.	1-1

8.2.3.10 VplComponent

The VplComponent element consists of several Vendor Part Library (VPL) component descriptions. This information becomes part of the Step where components are overlaid with information that is originated from the users BOM/AVL files, combined with any External Vendor Parts Library (EVPL)

Database. It presents the original EDA data (i.e. the data as it was read from an EDA database), after it was processed with a CAM tool's Assembly Merge (Bom Merge, Library Merge and Board Merge) function.

The `cadAvlMpn` and the `cadAvlVendor` attributes contain the MPN and Vendor values as they were read from the user BOM/AVL file, while the `VplMpn` and the `VplVendor` attributes contain these values as they were set from the EVPL Database.

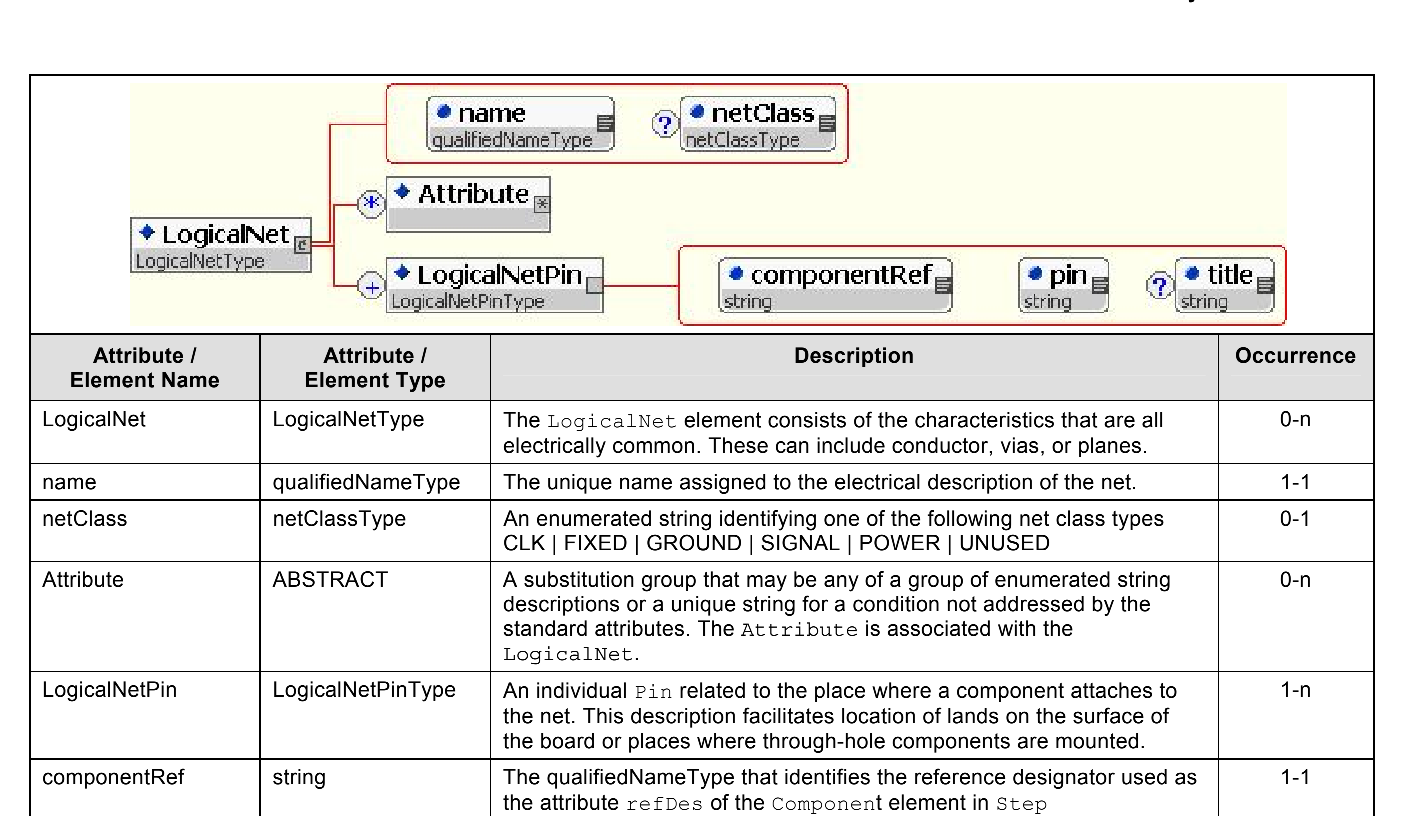


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
VplComponent	VplComponentType	A nested element of the Step functions that describes a component which has been extracted from a vendor parts library.	0-n
componentRef	qualifiedNameType	The name of the Component element that corresponds to the definition extracted from the vendor parts library.	1-1
bomItemRef	qualifiedNameType	A reference to the bomItem description which identifies the OEM Design Number and quantity used in the particular assembly.	1-1
VplPackageRef	qualifiedNameType	A reference to a Vpl package 'name' if the `PackageRef` of the Component is not appropriate.	0-1
CadVmpn	CadVmpnType	The individual CAD vendor manufacturing part numbers that correlates to the particular component referenced by the VplComponent.	1-n
CadMpn	string	The manufacturer's part number for the particular component.	1-1
cadAvlVendor	string	The name of the approved supplier of the part.	1-1
cadVplMpn	string	The vendor part library description and manufacturer's part number.	0-1
cadVplVendor	string	The name of the approved supplier of the part as noted in the vendor part library.	0-1
qualify	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the vendor part has been qualified; FALSE indicates that it has not been qualified. If the attribute is not present the qualification is unknown.	1-1
chosen	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the vendor part has been chosen; FALSE indicates that it has not been chosen. If the attribute is not present the fact that the vendor part has been choosen is unknown.	1-1

8.2.3.11 LogicalNet

The `LogicalNet` section is a list of `LogicalNet` elements, each with a name and a group of component/pin location(s). It enables the labeling of each pin with the net to which it belongs. The `PhyNetGroupList` is another representation of a netlist, using physical board locations instead of logical pins.

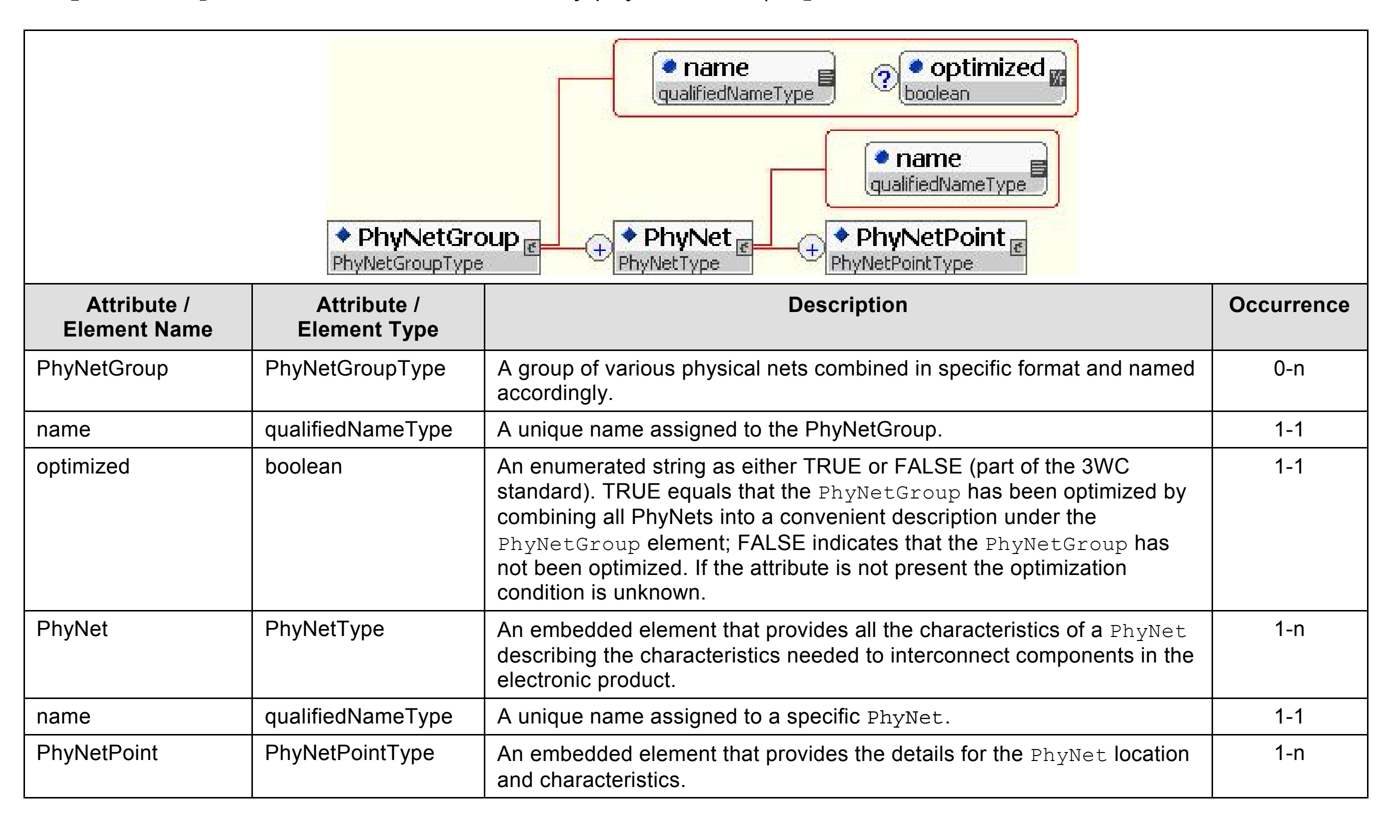
`LogicalNet` elements read from the CAD system in the form of component pins connectivity. Each `LogicalNet` contains the net name and a set of `LogicalNetPin`. Each `LogicalNetPin` points to a pin on a component.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LogicalNet	LogicalNetType	The LogicalNet element consists of the characteristics that are all electrically common. These can include conductor, vias, or planes.	0-n
name	qualifiedNameType	The unique name assigned to the electrical description of the net.	1-1
netClass	netClassType	An enumerated string identifying one of the following net class types CLK | FIXED | GROUND | SIGNAL | POWER | UNUSED	0-1
Attribute	ABSTRACT	A substitution group that may be any of a group of enumerated string descriptions or a unique string for a condition not addressed by the standard attributes. The Attribute is associated with the LogicalNet.	0-n
LogicalNetPin	LogicalNetPinType	An individual Pin related to the place where a component attaches to the net. This description facilitates location of lands on the surface of the board or places where through-hole components are mounted.	1-n
componentRef	string	The qualifiedNameType that identifies the reference designator used as the attribute refDes of the Component element in Step It is the reference to the component that is connected by the particular Pin and becomes a part of the electrical description of the net.	1-1
pin	string	An identification of the component pin that becomes a part of the electrical description.	1-1
title	string	An alternate method of relating the pin information providing characteristics of the component lead or termination description.	0-1

8.2.3.12 PhyNetGroup

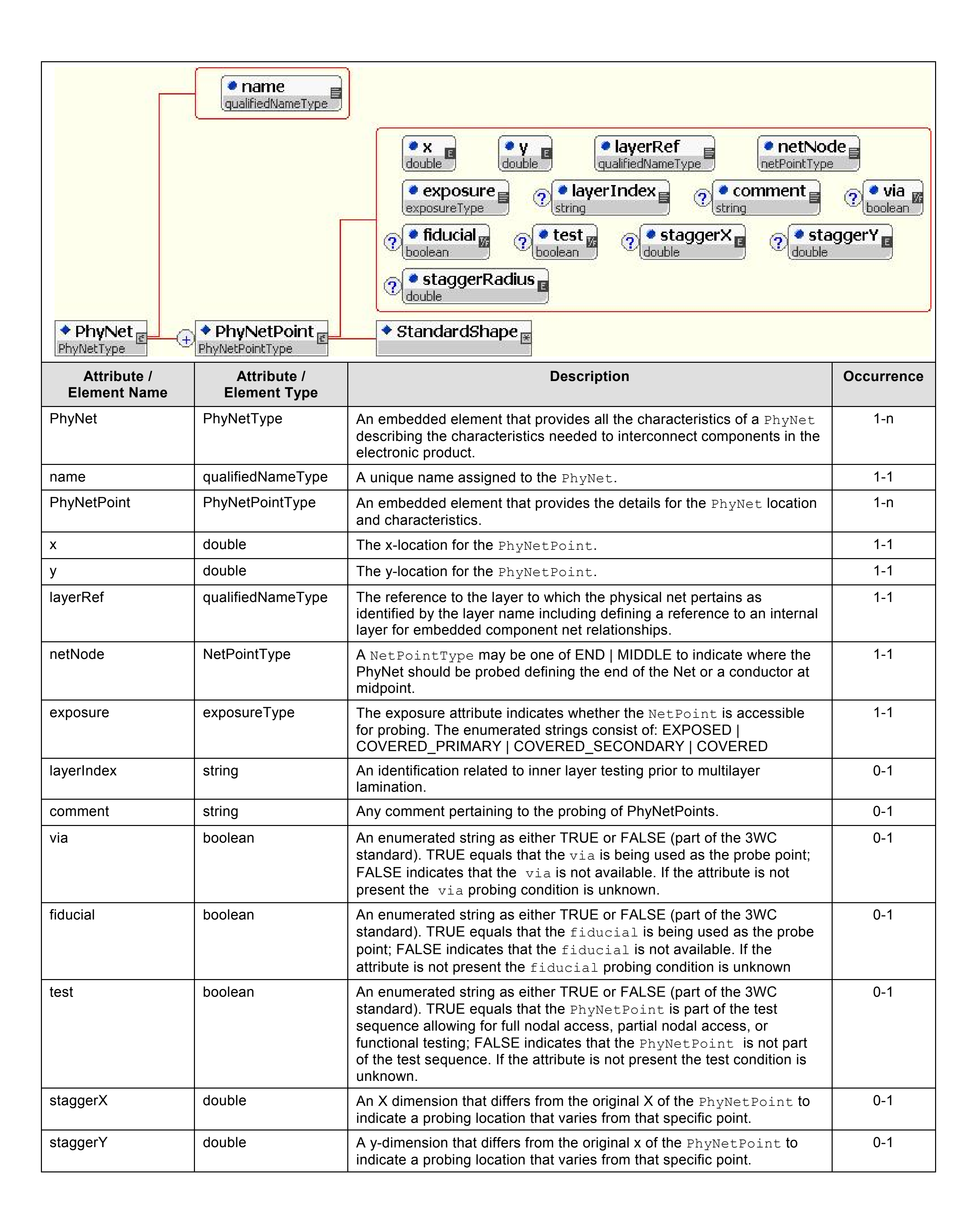
The PhyNetGroup element consists various physical electrical connections. The group of nets may be combined from individual layers and submitted to a netlist analyzer or read from netlist files. Each PhyNetGroup, contains a set of one to many physical nets (PhyNets).



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
PhyNetGroup	PhyNetGroupType	A group of various physical nets combined in specific format and named accordingly.	0-n
name	qualifiedNameType	A unique name assigned to the PhyNetGroup.	1-1
optimized	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the PhyNetGroup has been optimized by combining all PhyNets into a convenient description under the PhyNetGroup element; FALSE indicates that the PhyNetGroup has not been optimized. If the attribute is not present the optimization condition is unknown.	1-1
PhyNet	PhyNetType	An embedded element that provides all the characteristics of a PhyNet describing the characteristics needed to interconnect components in the electronic product.	1-n
name	qualifiedNameType	A unique name assigned to a specific PhyNet.	1-1
PhyNetPoint	PhyNetPointType	An embedded element that provides the details for the PhyNet location and characteristics.	1-n

8.2.3.12.1 PhyNet

The PhyNet element consists of one to many points that are essentially the nodes for the physical description of all the conductive elements that become a part of the Net on a particular surface of the board. The PhyNetPoint is only available on either top or bottom, unless the concepts are used for embedded passive description.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
PhyNet	PhyNetType	An embedded element that provides all the characteristics of a `PhyNet` describing the characteristics needed to interconnect components in the electronic product.	1-n
name	qualifiedNameType	A unique name assigned to the `PhyNet`.	1-1
PhyNetPoint	PhyNetPointType	An embedded element that provides the details for the `PhyNet` location and characteristics.	1-n
x	double	The x-location for the `PhyNetPoint`.	1-1
y	double	The y-location for the `PhyNetPoint`.	1-1
layerRef	qualifiedNameType	The reference to the layer to which the physical net pertains as identified by the layer name including defining a reference to an internal layer for embedded component net relationships.	1-1
netNode	NetPointType	A `NetPointType` may be one of END | MIDDLE to indicate where the PhyNet should be probed defining the end of the Net or a conductor at midpoint.	1-1
exposure	exposureType	The exposure attribute indicates whether the `NetPoint` is accessible for probing. The enumerated strings consist of: EXPOSED | COVERED_PRIMARY | COVERED_SECONDARY | COVERED	1-1
layerIndex	string	An identification related to inner layer testing prior to multilayer lamination.	0-1
comment	string	Any comment pertaining to the probing of PhyNetPoints.	0-1
via	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the `via` is being used as the probe point; FALSE indicates that the `via` is not available. If the attribute is not present the `via` probing condition is unknown.	0-1
fiducial	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the `fiducial` is being used as the probe point; FALSE indicates that the `fiducial` is not available. If the attribute is not present the `fiducial` probing condition is unknown	0-1
test	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the `PhyNetPoint` is part of the test sequence allowing for full nodal access, partial nodal access, or functional testing; FALSE indicates that the `PhyNetPoint` is not part of the test sequence. If the attribute is not present the test condition is unknown.	0-1
staggerX	double	An X dimension that differs from the original X of the `PhyNetPoint` to indicate a probing location that varies from that specific point.	0-1
staggerY	double	A y-dimension that differs from the original x of the `PhyNetPoint` to indicate a probing location that varies from that specific point.	0-1

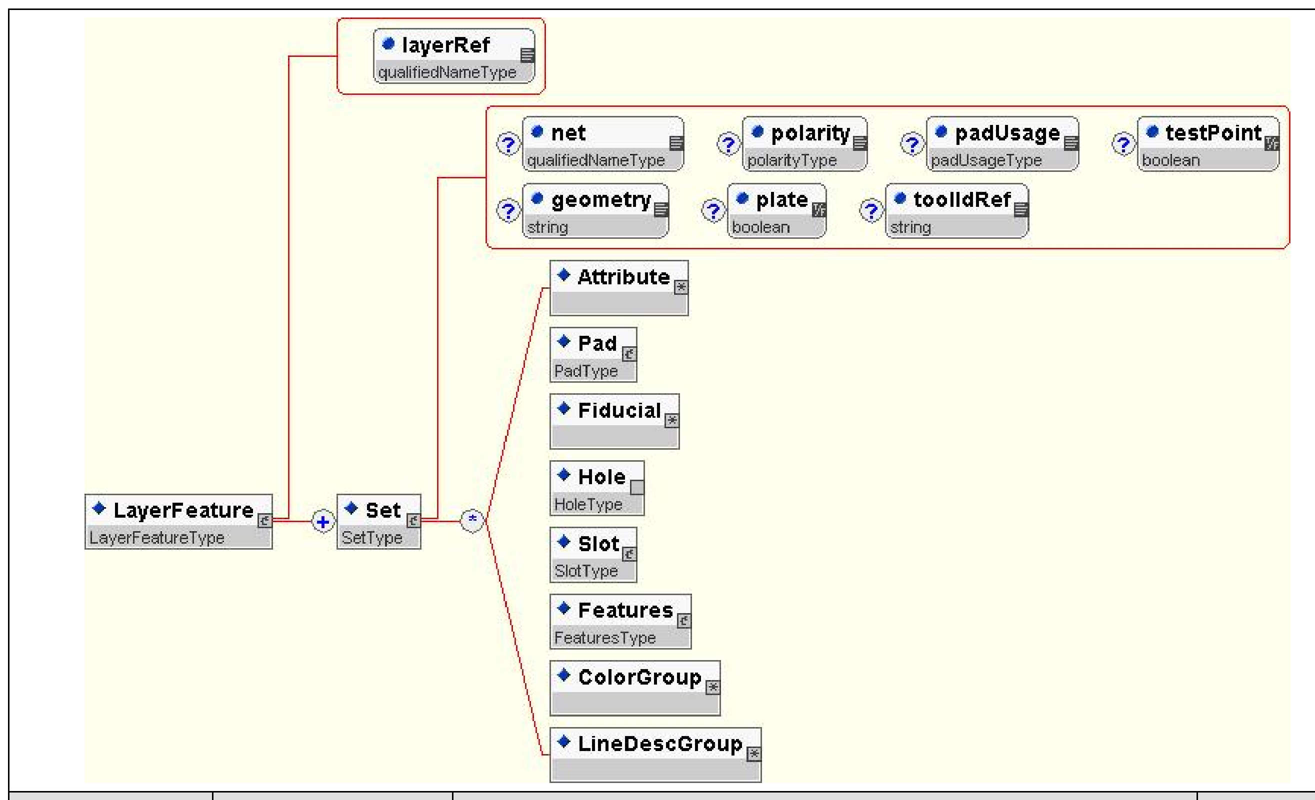
staggerRadius	double	A numerical value that indicates a radius taken from the original x-y point description in the direction of an open conductor that may be probed at its center.	0-1
StandardShape	ABSTRACT	A substitution group that permits the substitution of any of the `StandardPrimitive` shapes in accordance with their individual descriptions. A predefined `StandardPrimitive` may also be instantiated by its unique "id" when the feature is contained in the DictionaryStandard. When a reference is made to the dictionary predefined primitive the Units must match.	1-1

8.2.3.13 LayerFeature

The `LayerFeature` element contains all the physical features located on all layers. These features reference `StandardPrimitive` or `UserPrimitive` under the substitution group identification of `StandardShape` or `UserShape`. All shapes may be identified through a reference to predefined primitives contained in `DictionaryStandard` or `DictionaryUser`. Shapes may also be instantiated in the file by substitution of the `Feature` element with the shape name. All characteristics of any shape must be present when the substitution takes place.

An individual `LayerFeature` can be thought of as artwork and these two-dimensional descriptions become the main body of the `Step` data. The information is contained in `LayerFeature` elements and includes several different elements, each corresponding to a layer defined earlier in the `Layer` element.

The `Set` element defines modal attributes (attributes are in effect for all subsequent graphics contained in the set until changed). The only one important characteristic for the set graphic is the `polarity` attribute that can be POSITIVE (draw) or NEGATIVE (erase). The existence of negative features is the reason for the importance of the order.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LayerFeature	LayerFeatureType	An element that contains various sets of features that are grouped into various segments, each with applicability to define the features on a specific layer. The conditions relate to the type of features that are contained within the `LayerFeature` element and these are grouped according to the usage that the two-dimensional graphics have for providing graphical images on printed boards documentation or assembly descriptions. These conditions are defined through `layerRef`.	0-n
layerRef	qualifiedNameType	The reference to the unique layer name to which the `LayerFeature`(s) pertain.	1-1
Set	SetType	The multiple `Set` elements and attributes used to define specific features associated with a specific layer as identified by the layer `contextType`.	1-n
net	qualifiedNameType	The electrical relationship of any feature, through the name of the `PhyNet`, when the `Set` feature has conductivity checked in the `PhyNetPoint` descriptions. This attribute is left blank if the `Set` descriptions are for other than printed board fabrication or assembly conductivity.	0-1
polarity	polarityType	Polarity indicates whether the information described in the `Set` is POSITIVE | NEGATIVE. A NEGATIVE connotation can be used to describe the removal of a dark field to the specific dimensions described for another attribute. Thus, a surface that contains islands may have the islands described in a negative format.	0-1
padUsage	padUsageType	An indication as to the usage of any pad that becomes a part of the `LayerFeature Set`. The descriptions are enumerated strings and must be one of the following: TOE | VIA | BAD_BOARD_MARK | GLOBAL_FIDUCIAL | GOOD_PANEL_MARK | LOCAL_FIDUCIAL | TOOLING_HOLE | NONE.	0-1
testPoint	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE indicates that the feature is a candidate for a `testPoint` used for either in-circuit or functional testing. FALSE indicates that it is not.	0-1

geometry	string	An identification to describe the overall geometry of the features contained in the Set and their particular application to the electronic product.	0-1
plate	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE indicates that the feature is plated in a secondary operation. FALSE indicates that it is not.	0-1
toolIdRef	string	A reference to the DrillTool identification (id) defined in the DrillTool instance of the Layer section. This feature is used to associate the toolSize with features that are part of the Set.	0-1
Attribute	ABSTRACT	A substitution group that may be any of a group of enumerated string descriptions or a unique string for a condition not addressed by the standard attributes. The Attribute is associated with the LayerFeature Set.	0-n
Pad	PadType	A series of pads that are associated with the LayerFeature Set.	0-n
Fiducial	ABSTRACT	A substitution that consists of three elements that may be used to replace the Fiducial element. When the Fiducial element is substituted it **shall** be by a GlobalFiducial, GoodPanelMark, LocalFiducial or BadBoardMark.	0-n
Hole	HoleType	A series of holes associated with the LayerFeature Set.	0-n
Slot	SlotType	A series of slots associated with the LayerFeature Set.	0-n
Features	FeaturesType	An embedded element that defines a substitution group of any predefined StandardShape or UserShape that may be instantiated as a part of the LayerFeature Set.	0-n
ColorGroup	ABSTRACT	A substitution group that permits assigning a particular color through instantiating the three basic colors or by providing a reference to a predefined Color in DictionaryColor.	0-n
LineDescGroup	ABSTRACT	A substitution group that specifies the LineWidth and LineEnd characteristics of a Feature that requires that description. If a predefined feature is instantiated the presents of a LineDescGroup will override the previously defined LineDesc.	0-n

```
<Step name = "KarensFabricationPanel">
   <Datum x = "0.00" y = "0.00"/>
      <Profile>
         <Polygon>
            <PolyBegin x = "-305.00" y = "-230.00"/>
            <PolyStepSegment x = "-305.00" y = "230.00"/>
            <PolyStepSegment x = "305.00" y = "230.00"/>
            <PolyStepSegment x = "305.00" y = "-230.00"/>
            <PolyStepSegment x = "-305.00" y = "-230.00"/>
         </Polygon>
      </Profile>
      <LayerFeature layerRef = "KarensMultilayer">
         <Set>
            <Slot name = "Tooling Slots" platingStatus = "NONPLATED" plusTol = "0.02" minusTol = "0.00">
               <Outline>
                  <Polygon>
                     <PolyBegin x = "1.59" y = "209.29"/>
                     <PolyStepSegment x = "1.59" y = "210.71"/>
                     <PolyStepCurve x = "-1.59" y = "210.71" centerX = "0.00" centerY = "210.71"/>
                     <PolyStepSegment x = "-1.59" y = "209.29"/>
                     <PolyStepCurve x = "1.59" y = "209.29" centerX = "0.00" centerY = "209.29"/>
               </Outline>
               <Outline>
                  <Polygon>
                     <PolyBegin x = "1.59" y = "-209.29"/>
                     <PolyStepSegment x = "1.59" y = "-210.71"/>
                     <PolyStepCurve x = "-1.59" y = "-210.71" centerX = "0.00" centerY = "-210.71" clockwise = "TRUE"/>
                     <PolyStepSegment x = "-1.59" y = "-209.29"/>
                     <PolyStepCurve x = "1.59" y = "-209.29" centerX = "0.00" centerY = "-209.29" clockwise = "TRUE"/>
                  </Polygon>
               </Outline>
               <Outline>
                  <Polygon>
                     <PolyBegin x = "289.29" y = "1.59"/>
                     <PolyStepSegment x = "290.71" y = "1.59"/>
                     <PolyStepCurve x = "290.71" y = "-1.59" centerX = "290.71" centerY = "0.00" clockwise = "TRUE"/>
                     <PolyStepSegment x = "289.29" y = "-1.59"/>
                     <PolyStepCurve x = "289.29" y = "1.59" centerX = "289.29" centerY = "0.00" clockwise = "TRUE"/>
                  </Polygon>
               </Outline>
                  <Outline>
                     <Polygon>
                        <PolyBegin x = "-289.29" y = "1.59"/>
                        <PolyStepSegment x = "-290.71" y = "1.59"/>
                        <PolyStepCurve x = "-290.71" y = "-1.59" centerX = "-290.71" centerY = "0.00"/>
                        <PolyStepSegment x = "-1.59" y = "-289.29"/>
                        <PolyStepCurve x = "-289.29" y = "1.59" centerX = "-289.29" centerY = "0.00"/>
                     </Polygon>
                  </Outline>
               </Slot>
               <LineDesc lineEnd = "NONE" lineWidth = "0.00"/>
            </Set>
         </LayerFeature>
```

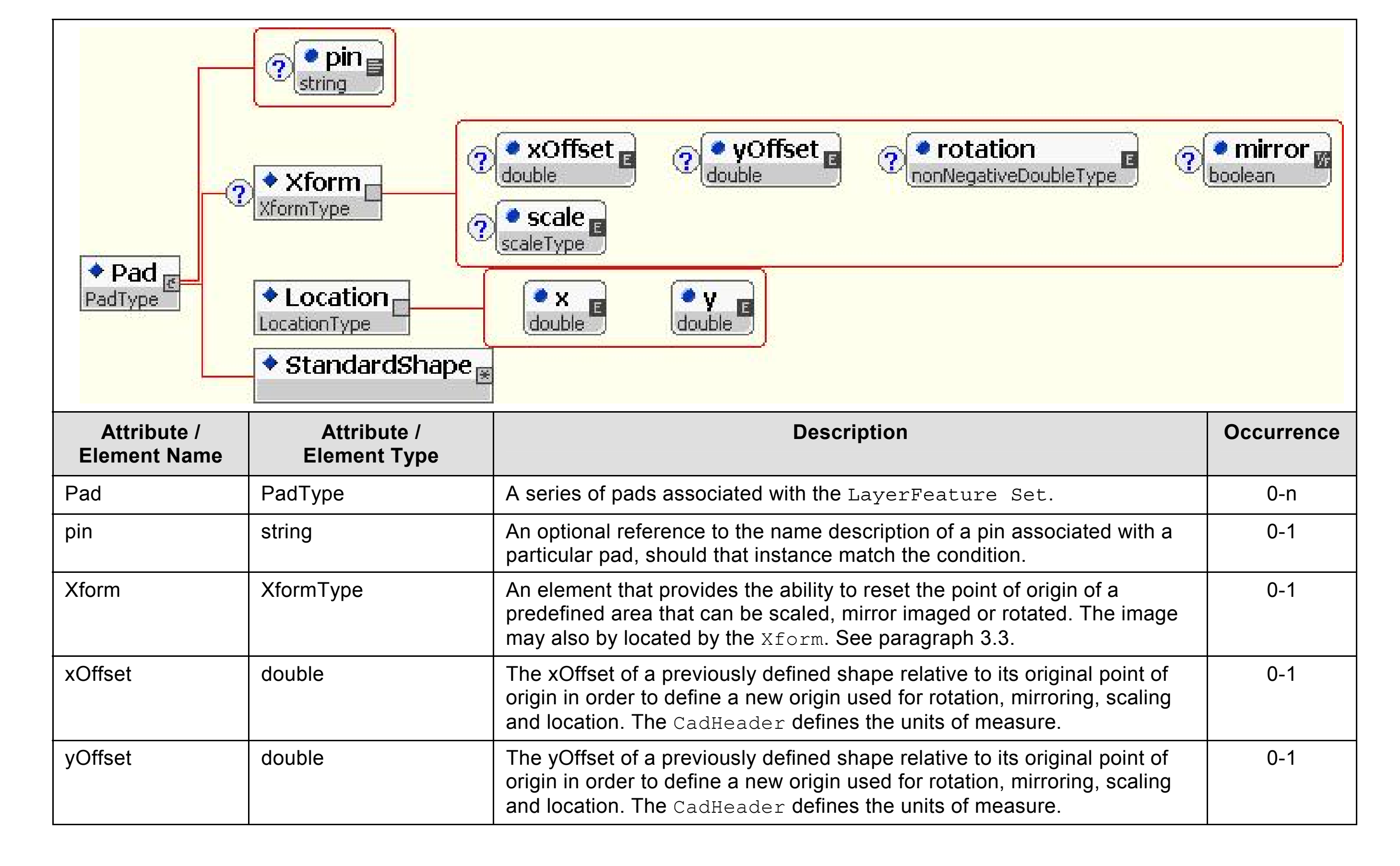
8.2.3.13.1 Attribute

The `Attribute element` consists of any attributes that pertain to any of the elements in a particular `Set` . There may be from one to many unique `Attribute` occurrences within each `Set`. Any `Attribute` description may be one standard enumerated string attributes or a unique description established by the user of the file.

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Attribute	ABSTRACT	A substitution group that may be any of a group of enumerated string descriptions or a unique string for a condition not addressed by the standard attributes. The `Attribute` is associated with the `LayerFeature Set`.	0-n

8.2.3.13.2 Pad

The `Pad` element represents an individual pad. `Pads` are features with a center (`x, y`), a standard primitive shape either pre-defined in the `DictionaryStandard`, or instanced at the time the `Set` is defined. The `Pad` may be changed through the `Xform` element (located, rotated, mirrored or scaled). `Rotation` is any number of degrees, although 90º multiples is the usual angle; positive rotation is always counter-clockwise as viewed from the board TOP (primary side). When `mirror` is set to MIRROR it indicates that all x dimensions are set to a–x value. For scaling the `Pad`, all `x` and `y` dimensions of a `geometry` are multiplied by the `scale` attribute. The scale factor does not apply to angular values. The `Pad` may have an appropriate `pin` attribute.

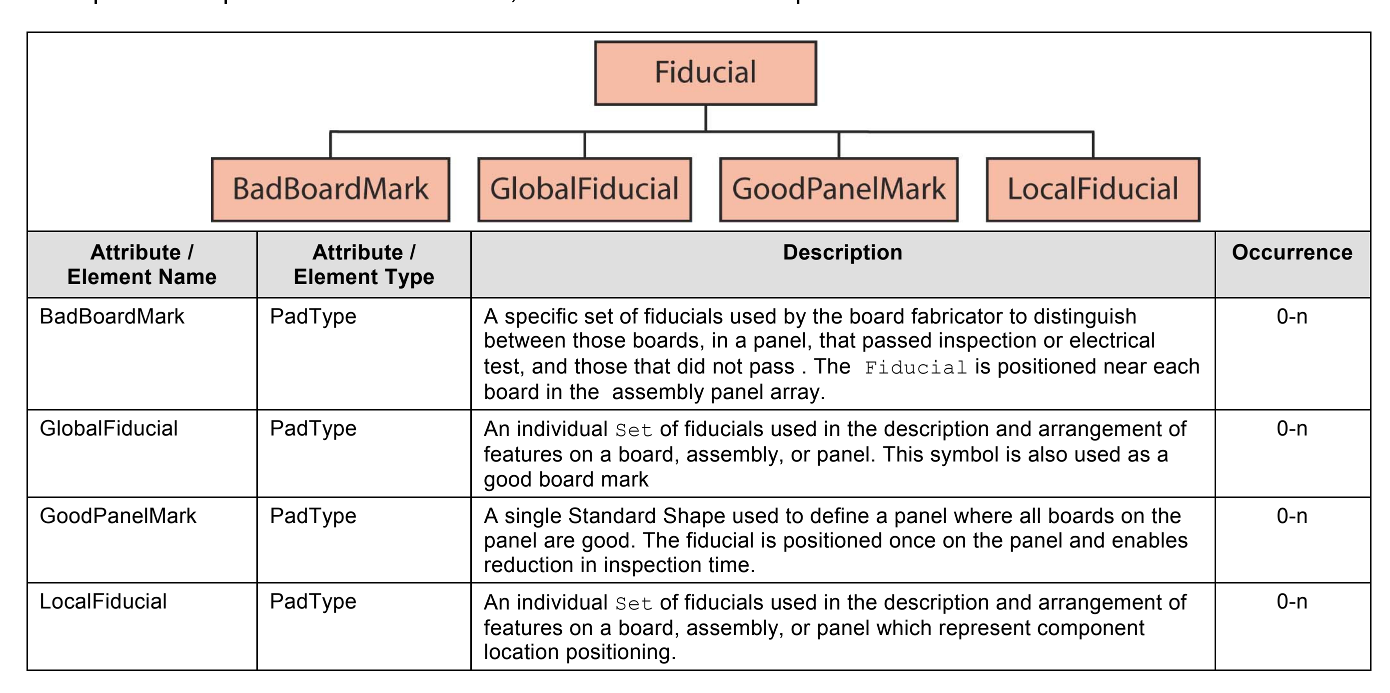


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Pad	PadType	A series of pads associated with the `LayerFeature Set`.	0-n
pin	string	An optional reference to the name description of a pin associated with a particular pad, should that instance match the condition.	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined area that can be scaled, mirror imaged or rotated. The image may also by located by the `Xform`. See paragraph 3.3.	0-1
xOffset	double	The xOffset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
yOffset	double	The yOffset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1

rotation	nonNegativeDouble Type	Defines the rotation of a shape about the local origin in degrees. Positive rotation is always counter-clockwise as viewed from the board TOP (primary side). Degree accuracy is expressed as a two place decimal i.e., 45.15; 62.34	0-1
mirror	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the image is mirrored; FALSE indicates that it is not.	0-1
scale	scaleType	An attribute that defines a "double" dimension whose minExclusiveValue=0.0 representing the multiplication factor of all x and y dimensions. The scale factor does not apply to angular values.	0-1
Location	LocationType	The location of the image defined by the standard shape or a pre-defined standard shape of the pad. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate upon which a features' point-of-origin is located, relative to the point of origin of the product on which a component is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
y	double	The x coordinate upon which a features' point-of-origin is located, relative to the point of origin of the product on which a component is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
StandardShape	ABSTRACT	A substitution group that may call for any `StandardPrimitive`, instantiated by describing their unique features or by referencing a predefined primitive contained in the `DictionaryStandard`.	1-1

8.2.3.13.3 Fiducial

A specific set of fiducials used by the board fabricator to distinguish between those boards, in a panel, that passed inspection or electrical test, and those that did not pass.



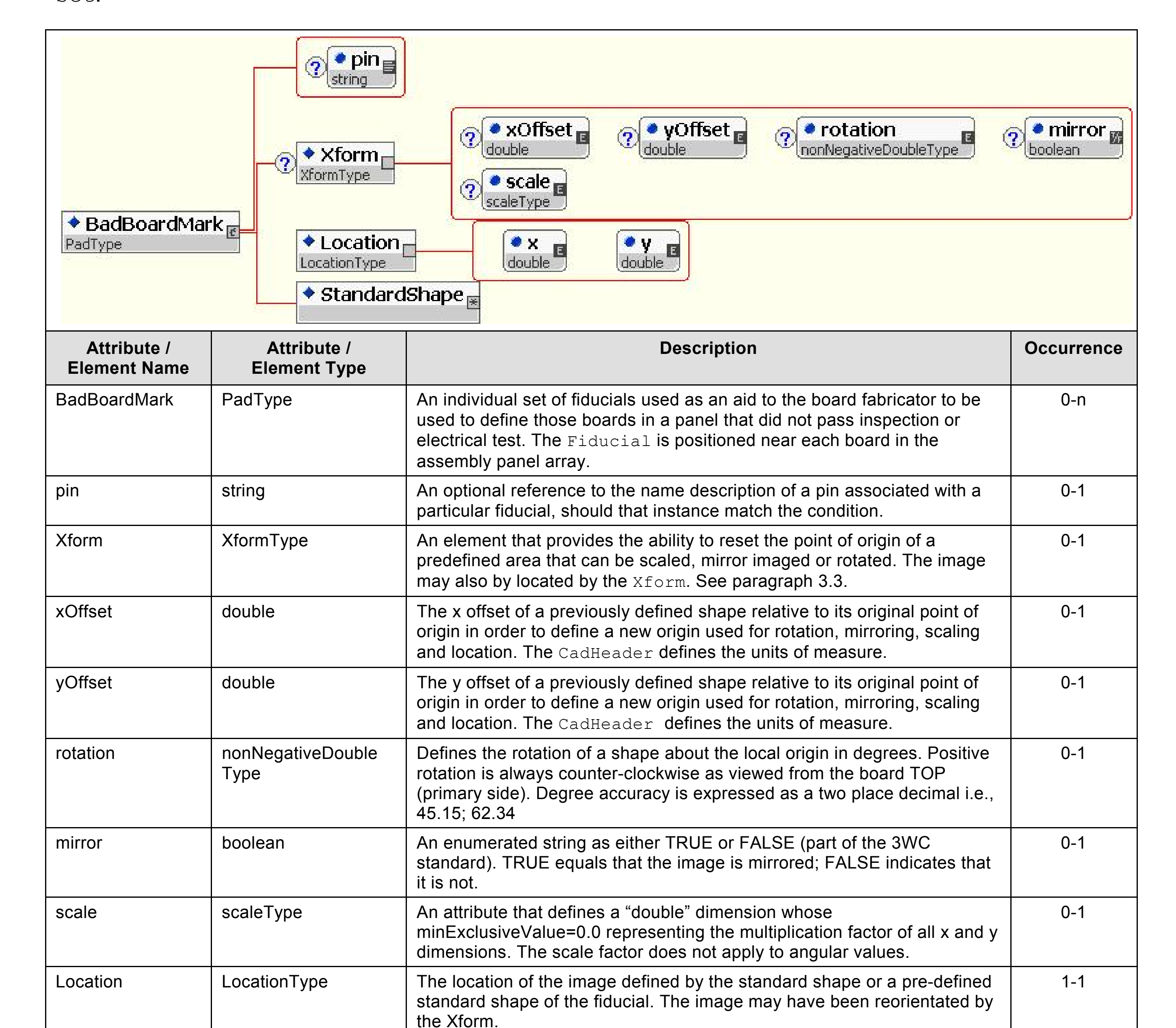
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
BadBoardMark	PadType	A specific set of fiducials used by the board fabricator to distinguish between those boards, in a panel, that passed inspection or electrical test, and those that did not pass . The `Fiducial` is positioned near each board in the assembly panel array.	0-n
GlobalFiducial	PadType	An individual `Set` of fiducials used in the description and arrangement of features on a board, assembly, or panel. This symbol is also used as a good board mark	0-n
GoodPanelMark	PadType	A single Standard Shape used to define a panel where all boards on the panel are good. The fiducial is positioned once on the panel and enables reduction in inspection time.	0-n
LocalFiducial	PadType	An individual `Set` of fiducials used in the description and arrangement of features on a board, assembly, or panel which represent component location positioning.	0-n

- **BadBoardMark**

The `BadBoardMark` element provides a list of images intended to represent a symbol known as a fiducial which works with equipment vision systems to identify whether the board in the array is good or not. The determination is usually made by the board fabricator and he covers the fiducial (`BadBoardMark`) to indicate that the board should not be assembled with components.

These images are usually described in the form of a `StandardShape` and may appear on any `Layer` as a `LayerFeature`. The `BadBoardMark` may also be identified as a separate `Set`, thus arranging all of the `BadBoardMark elements` that identify good and bad boards on an assembly array, or manufacturing panel.

If treated individually, `BadBoardMark` elements may appear multiple times within the `LayerFeature Set`.



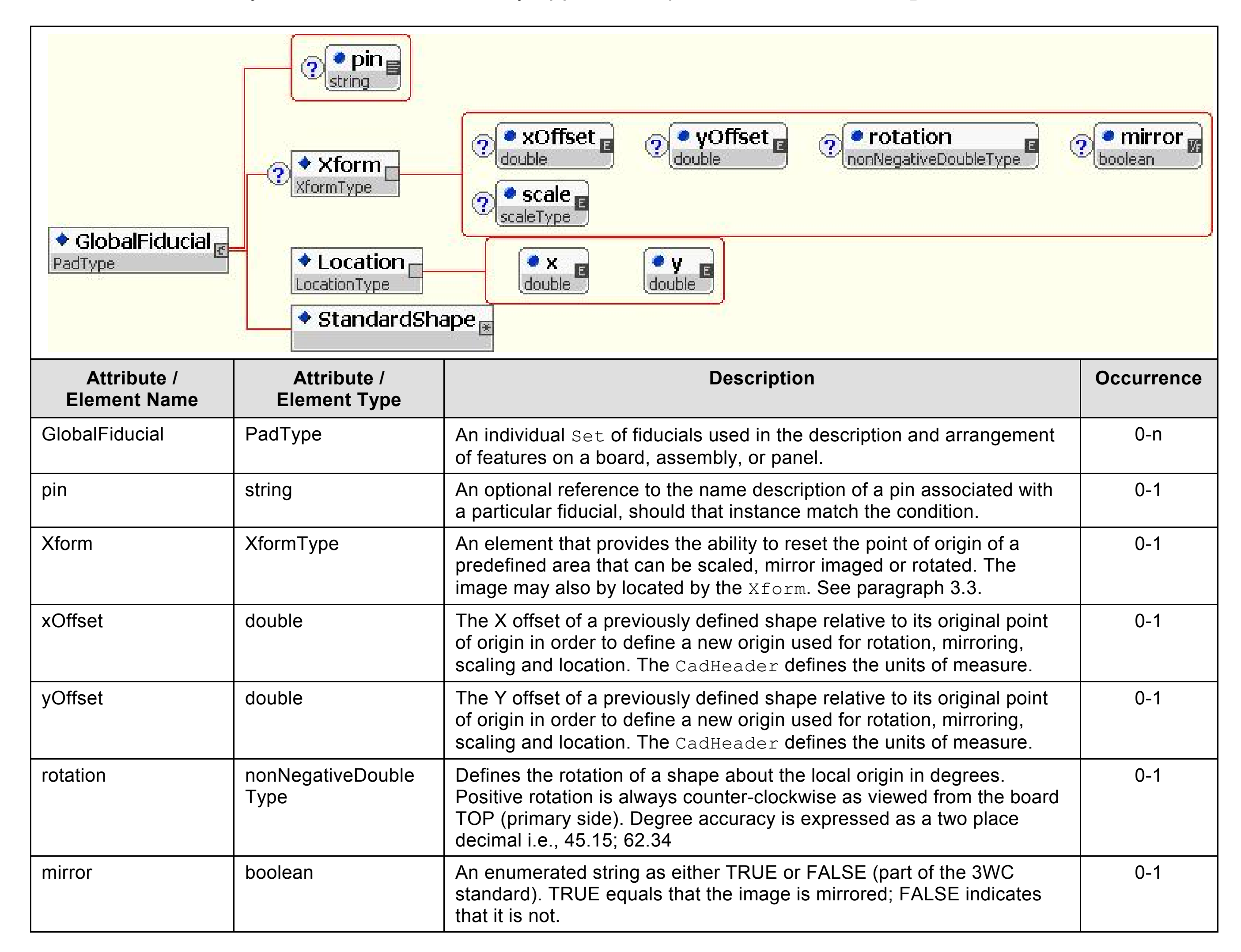
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
BadBoardMark	PadType	An individual set of fiducials used as an aid to the board fabricator to be used to define those boards in a panel that did not pass inspection or electrical test. The `Fiducial` is positioned near each board in the assembly panel array.	0-n
pin	string	An optional reference to the name description of a pin associated with a particular fiducial, should that instance match the condition.	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined area that can be scaled, mirror imaged or rotated. The image may also by located by the `Xform`. See paragraph 3.3.	0-1
xOffset	double	The x offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
yOffset	double	The y offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
rotation	nonNegativeDouble Type	Defines the rotation of a shape about the local origin in degrees. Positive rotation is always counter-clockwise as viewed from the board TOP (primary side). Degree accuracy is expressed as a two place decimal i.e., 45.15; 62.34	0-1
mirror	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the image is mirrored; FALSE indicates that it is not.	0-1
scale	scaleType	An attribute that defines a “double” dimension whose minExclusiveValue=0.0 representing the multiplication factor of all x and y dimensions. The scale factor does not apply to angular values.	0-1
Location	LocationType	The location of the image defined by the standard shape or a pre-defined standard shape of the fiducial. The image may have been reorientated by the Xform.	1-1

x	double	The x coordinate upon which a features' point-of-origin is located, relative to the point of origin of the product on which a fiducial is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
y	double	The x coordinate upon which a features' point-of-origin is located, relative to the point of origin of the product on which a fiducial is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
StandardShape	ABSTRACT	A substitution group that may call for any `StandardPrimitive`, instantiated by describing their unique features or by referencing a predefined primitive contained in the `DictionaryStandard`.	1-1

- **GlobalFiducial**

The `GlobalFiducial` element provides a list of images intended to represent a symbol known as a fiducial which works with assembly equipment vision systems to improve the positioning of the board or panel. These images are described in the form of a `StandardShape` and may appear on any `Layer` as a `LayerFeature`. The `GlobalFiducial` may also be identified as a separate `Set`, thus arranging all of the fiducials that position boards, assemblies, and assembly arrays in a panel format are considered in one `LayerFeature Set`.

If treated individually, `GlobalFiducial` may appear multiple times within the `LayerFeature Set`.



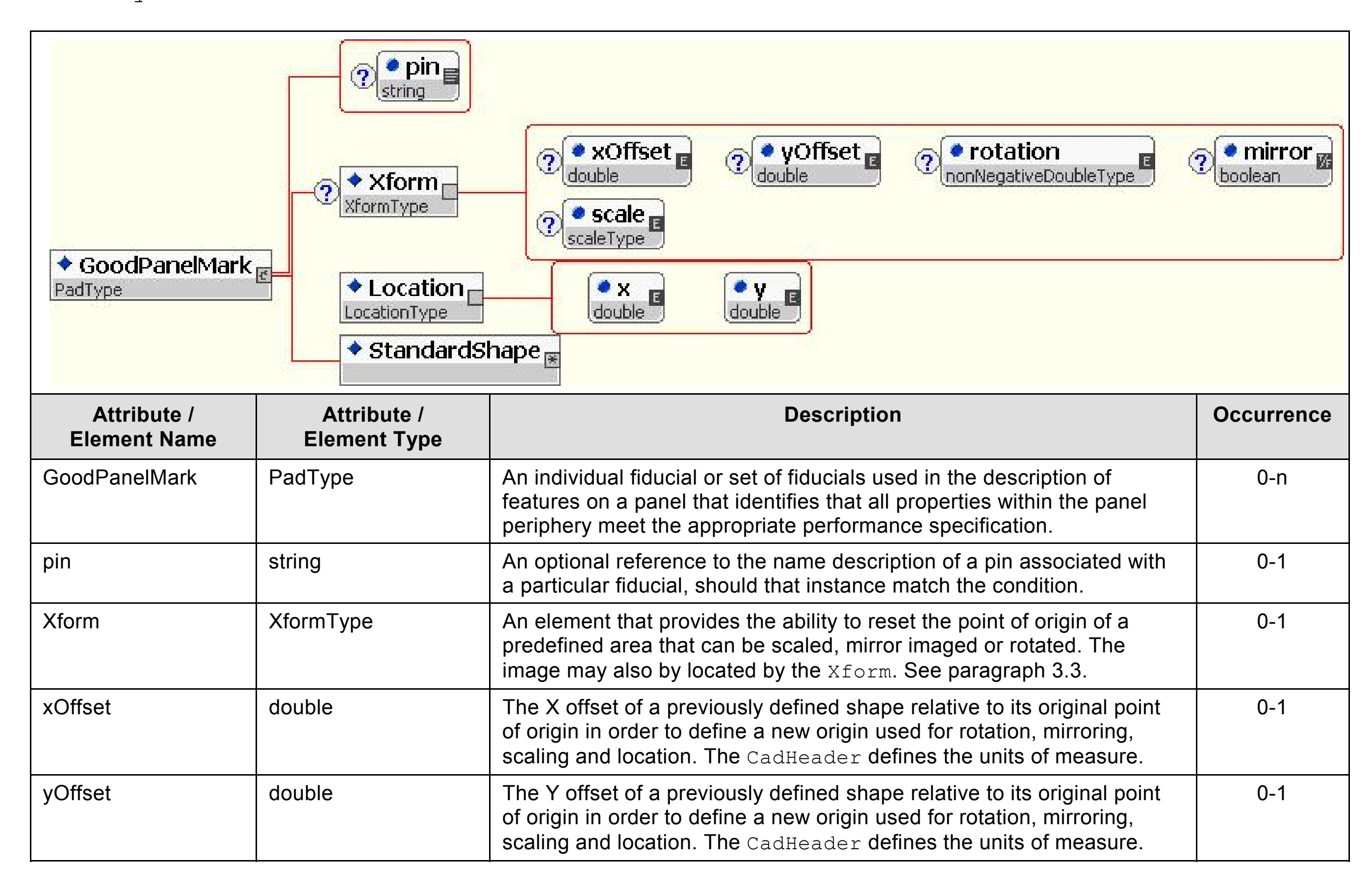
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
GlobalFiducial	PadType	An individual `Set` of fiducials used in the description and arrangement of features on a board, assembly, or panel.	0-n
pin	string	An optional reference to the name description of a pin associated with a particular fiducial, should that instance match the condition.	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined area that can be scaled, mirror imaged or rotated. The image may also by located by the `Xform`. See paragraph 3.3.	0-1
xOffset	double	The X offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
yOffset	double	The Y offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
rotation	nonNegativeDouble Type	Defines the rotation of a shape about the local origin in degrees. Positive rotation is always counter-clockwise as viewed from the board TOP (primary side). Degree accuracy is expressed as a two place decimal i.e., 45.15; 62.34	0-1
mirror	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the image is mirrored; FALSE indicates that it is not.	0-1

scale	scaleType	An attribute that defines a "double" dimension whose minExclusiveValue=0.0 representing the multiplication factor of all x and y dimensions. The scale factor does not apply to angular values.	0-1
Location	LocationType	The location of the image defined by the standard shape or a pre-defined standard shape of the fiducial. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate upon which a features' point-of-origin is located, relative to the point of origin of the product on which a fiducial is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
y	double	The x coordinate upon which a features' point-of-origin is located, relative to the point of origin of the product on which a fiducial is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
StandardShape	ABSTRACT	A substitution group that may call for any `StandardPrimitive`, instantiated by describing their unique features or by referencing a predefined primitive contained in the `DictionaryStandard`.	1-1

- **GoodPanelMark**

The `GoodPanelMark` element provides a single image intended to represent a symbol known as a fiducial which works with equipment vision systems to identify that all the boards in an array are good. The determination is usually made by the board fabricator. He makes sure that the `GoodPanelMark` fiducial is clearly visible to avoid having to check to see if there are any bad boards.

These images are usually described in the form of a `StandardShape` and may appear on any `Layer` as a `LayerFeature`.



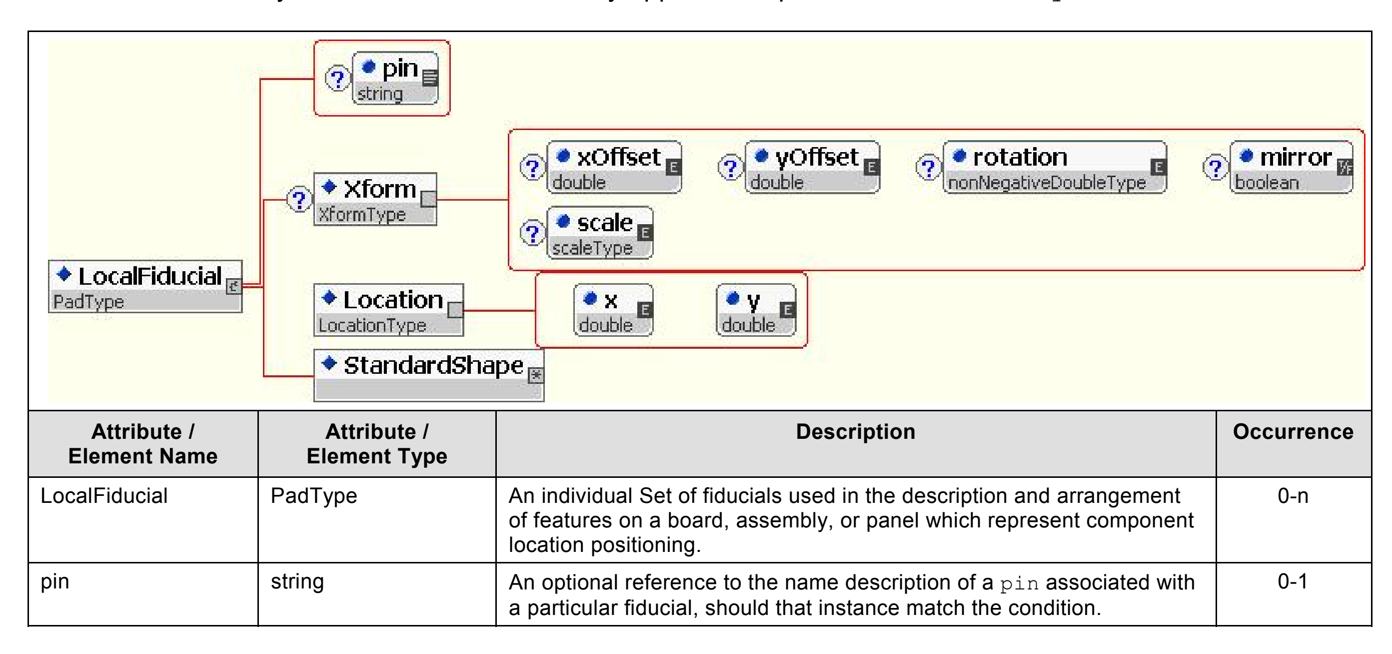
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
GoodPanelMark	PadType	An individual fiducial or set of fiducials used in the description of features on a panel that identifies that all properties within the panel periphery meet the appropriate performance specification.	0-n
pin	string	An optional reference to the name description of a pin associated with a particular fiducial, should that instance match the condition.	0-1
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined area that can be scaled, mirror imaged or rotated. The image may also by located by the `Xform`. See paragraph 3.3.	0-1
xOffset	double	The X offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
yOffset	double	The Y offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1

rotation	nonNegativeDouble Type	Defines the rotation of a shape about the local origin in degrees. Positive rotation is always counter-clockwise as viewed from the board TOP (primary side). Degree accuracy is expressed as a two place decimal i.e., 45.15; 62.34	0-1
mirror	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the image is mirrored; FALSE indicates that it is not.	0-1
scale	scaleType	An attribute that defines a "double" dimension whose minExclusiveValue=0.0 representing the multiplication factor of all x and y dimensions. The scale factor does not apply to angular values.	0-1
Location	LocationType	The location of the image defined by the standard shape or a pre-defined standard shape of the fiducial. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate upon which a features' point-of-origin is located, relative to the point of origin of the product on which a fiducial is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
y	double	The x coordinate upon which a features' point-of-origin is located, relative to the point of origin of the product on which a fiducial is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
StandardShape	ABSTRACT	A substitution group that may call for any `StandardPrimitive`, instantiated by describing their unique features or by referencing a predefined primitive contained in the `DictionaryStandard`.	1-1

- **LocalFiducial**

The `LocalFiducial` element provides a list of images intended to represent a symbol known as a fiducial which works with specific components that require the additional precision of assembly equipment vision systems to improve the positioning of the component during the assembly operation. These images are usually described in the form of a `StandardShape` and may appear on any `Layer` as a `LayerFeature`. The `LocalFiducial` may also be identified as a separate `Set`, thus arranging all of the fiducials that position components or other specific features on a board, assembly array, or manufacturing panel.

If treated individually, the `LocalFiducial` may appear multiple times within the `LayerFeature Set`.



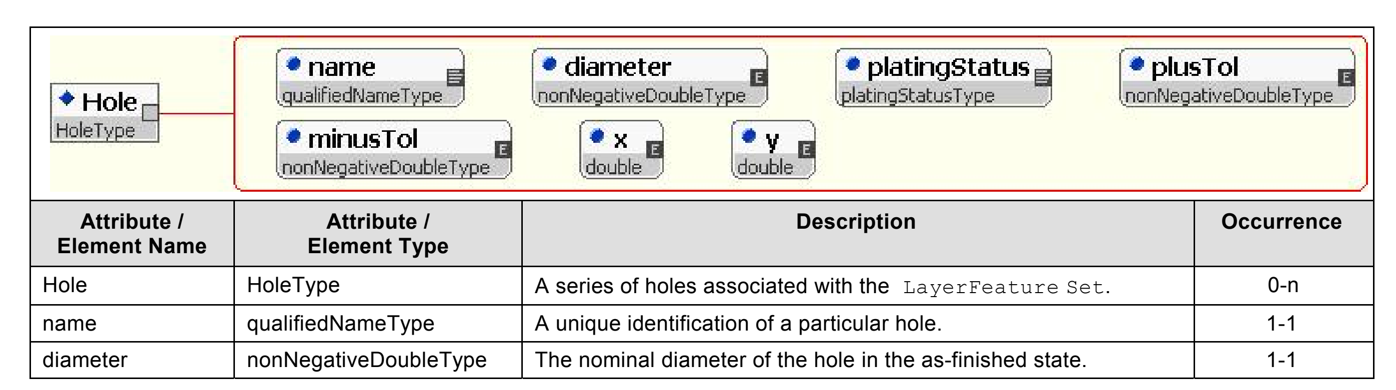
Attribute / Element Name	Attribute / Element Type	Description	Occurrence
LocalFiducial	PadType	An individual Set of fiducials used in the description and arrangement of features on a board, assembly, or panel which represent component location positioning.	0-n
pin	string	An optional reference to the name description of a `pin` associated with a particular fiducial, should that instance match the condition.	0-1

Xform	XformType	An element that provides the ability to reset the point of origin of a predefined area that can be scaled, mirror imaged or rotated. The image may also by located by the `Xform`. See paragraph 3.3.	0-1
xOffset	double	The x offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
yOffset	double	The y offset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
rotation	nonNegativeDouble Type	Defines the rotation of a shape about the local origin in degrees. Positive rotation is always counter-clockwise as viewed from the board TOP (primary side). Degree accuracy is expressed as a two place decimal i.e., 45.15; 62.34	0-1
mirror	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the image is mirrored; FALSE indicates that it is not.	0-1
scale	scaleType	An attribute that defines a "double" dimension whose minExclusiveValue=0.0 representing the multiplication factor of all x and y dimensions. The scale factor does not apply to angular values.	0-1
Location	LocationType	The location of the image defined by the standard shape or a pre-defined standard shape of the fiducial. The image may have been reorientated by the Xform.	1-1
x	double	The x coordinate upon which a features' point-of-origin is located, relative to the point of origin of the product on which a fiducial is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
y	double	The x coordinate upon which a features' point-of-origin is located, relative to the point of origin of the product on which a fiducial is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
StandardShape	ABSTRACT	A substitution group that may call for any `StandardPrimitive`, instantiated by describing their unique features or by referencing a predefined primitive contained in the `DictionaryStandard`.	1-1

8.2.3.13.4 Hole

The `Hole` element describes the characteristics of a particular hole, including naming the hole description with a unique name that may be reused. The main purpose of including hole in the Set means that specific information can be described as all the particular holes in one set of data. In this instance, the `layerRef` of `LayerFeature` is to the `Layer/Stackup` element which describes the `overallThickness` for those holes that go entirely through the board. For those holes that are buried or blind vias, the appropriate `Stackup` reference **shall** be used as a part of the `layerRef` of the `LayerFeature` descriptions of holes. This concept permits a replacement of the `Drill` file that usually accompanies a data transfer transaction.

The `Hole` element can occur multiple times within the `LayerFeature` element.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Hole	HoleType	A series of holes associated with the `LayerFeature Set`.	0-n
name	qualifiedNameType	A unique identification of a particular hole.	1-1
diameter	nonNegativeDoubleType	The nominal diameter of the hole in the as-finished state.	1-1

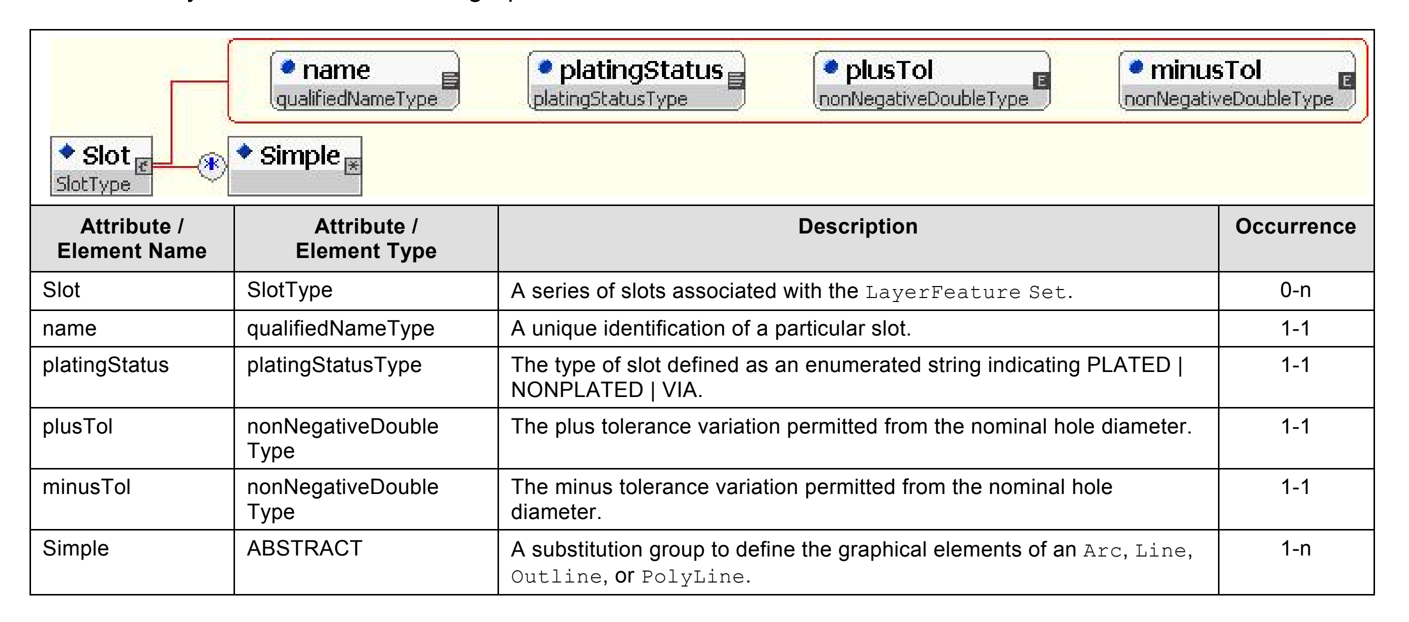
platingStatus	platingStatusType	The type of hole defined as an enumerated string indicating PLATED | NONPLATED | VIA.	1-1
plusTol	nonNegativeDoubleType	The plus tolerance variation permitted from the nominal hole diameter.	1-1
minusTol	nonNegativeDoubleType	The minus tolerance variation permitted from the nominal hole diameter.	1-1
x	double	The x-location of the hole.	1-1
y	double	The y-location of the hole.	1-1

8.2.3.13.5 Slot

The `Slot` element describes the characteristics of a particular slot, including naming the slot description with a unique name that may be reused. The main purpose of including slot in the `Set` means that specific information can be described for all the particular slots in one set of data.

The `layerRef` of `LayerFeature` is to the appropriate layers that contain the slot. A `Layer` name may also be assigned to the total board through the `Layer Span` function; this can describe the `overallThickness` for those slots that go entirely through the board. For those slots that are partially cut into the board, the appropriate `Stackup` reference **shall** be used as a part of the `layerRef` of the `LayerFeature` descriptions of slots.

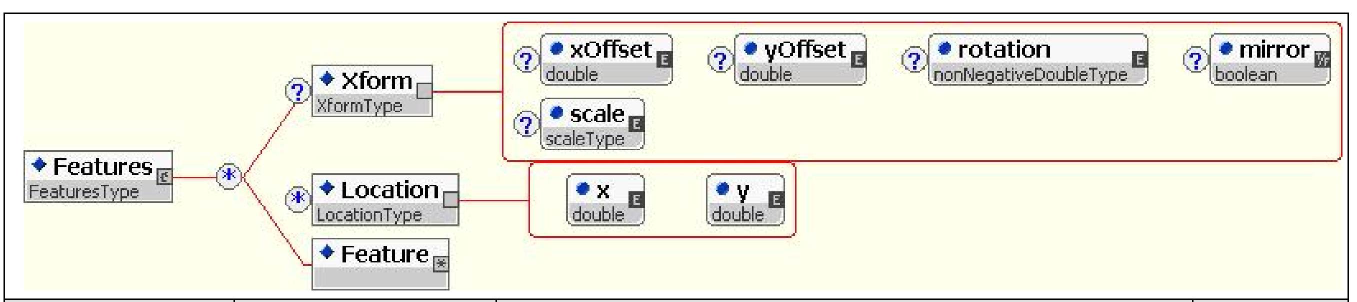
The `Slot` element can occur multiple times within the `LayerFeature` element. The graphical elements of `Line`, `Polyline`, `Arc`, and `Polygon` are used as substitution groups under the Simple primitive descriptions and are used to describe the characteristics of any particular `Slot`. There may be zero to many occurrences of these graphics.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Slot	SlotType	A series of slots associated with the `LayerFeature Set`.	0-n
name	qualifiedNameType	A unique identification of a particular slot.	1-1
platingStatus	platingStatusType	The type of slot defined as an enumerated string indicating PLATED | NONPLATED | VIA.	1-1
plusTol	nonNegativeDouble Type	The plus tolerance variation permitted from the nominal hole diameter.	1-1
minusTol	nonNegativeDouble Type	The minus tolerance variation permitted from the nominal hole diameter.	1-1
Simple	ABSTRACT	A substitution group to define the graphical elements of an `Arc`, `Line`, `Outline`, or `PolyLine`.	1-n

8.2.3.13.6 Features

An embedded element that defines a substitution group, whose characteristics are used to identify any `StandardShape` or `UserShape`. The description may come from a predefined stored element contained in `DictionaryStandard` or `DictionaryUser` or instantiated at the time a feature is described.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Features	FeaturesType	An embedded element that defines a substitution group of any predefined `StandardShape` or `UserShape` that may be instantiated as a part of the `LayerFeature Set`.	0-n
Xform	XformType	An element that provides the ability to reset the point of origin of a predefined area that can be scaled, mirror imaged or rotated. The image may also by located by the `Xform`. See paragraph 3.3.	0-1
xOffset	double	The xOffset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
yOffset	double	The yOffset of a previously defined shape relative to its original point of origin in order to define a new origin used for rotation, mirroring, scaling and location. The `CadHeader` defines the units of measure.	0-1
rotation	nonNegativeDouble Type	Defines the rotation of a shape about the local origin in degrees. Positive rotation is always counter-clockwise as viewed from the board TOP (primary side). Degree accuracy is expressed as a two place decimal i.e., 45.15; 62.34	0-1
mirror	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the image is mirrored; FALSE indicates that it is not.	0-1
scale	scaleType	An attribute that defines a “double” dimension whose minExclusiveValue=0.0 representing the multiplication factor of all x and y dimensions. The scale factor does not apply to angular values.	0-1
Location	LocationType	The location of the image defined by the standard shape or a pre-defined standard shape of the pad. The image may have been reorientated by the Xform.	0-n
x	double	The x coordinate upon which a features’ point-of-origin is located, relative to the point of origin of the product on which a component is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
y	double	The x coordinate upon which a features’ point-of-origin is located, relative to the point of origin of the product on which a component is positioned in accordance with the Cartesian coordinate system. The `CadHeader` defines the units of measure.	1-1
Feature	ABSTRACT	An element that identifies the substitution group of any pre-defined `StandardShape` or `UserShape` that can be instanced by the user at the time the layer feature is described.	0-n

8.2.3.13.7 ColorGroup

A substitution group characteristic used to identify any color required for the set. The description may come from a predefined stored element contained in `DictionaryColor` or instantiated at the time a feature is described.

ColorGroup			
Attribute / Element Name	**Attribute / Element Type**	**Description**	**Occurrence**
colorGroup	ABSTRACT	An element that identifies the substitution group of any pre-defined graphic shape or those shapes that can be instanced by the user at the time the layer feature is described.	0-n

8.2.3.13.8 LineDescGroup

A substitution group characteristic used to identify line description information. The description may come from a predefined stored element contained in `DictionaryLineDesc` or instantiated at the time a feature is described.

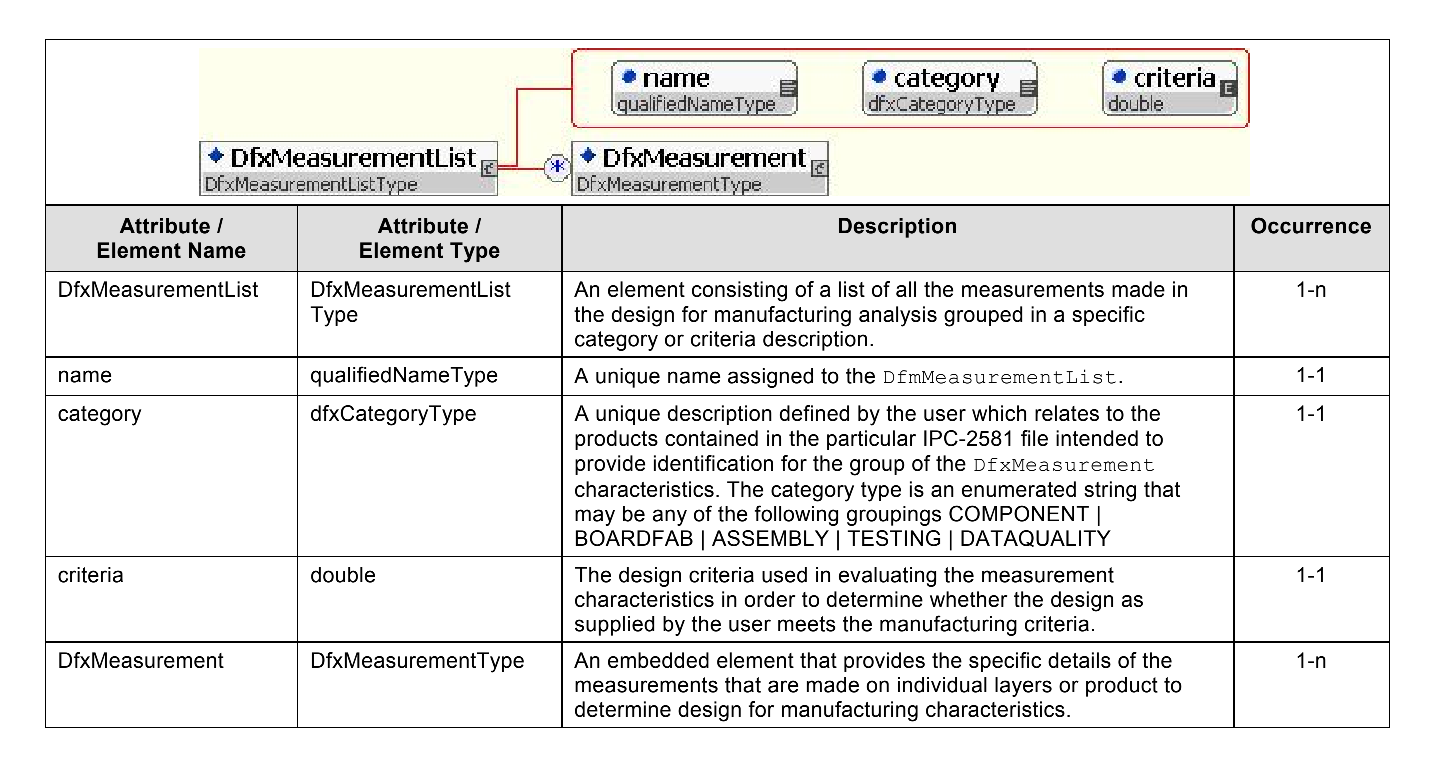
LineDescGroup			
Attribute / Element Name	**Attribute / Element Type**	**Description**	**Occurrence**
LineDescGroup	ABSTRACT	A substitution group that specifies the `LineWidth` and `LineEnd` characteristics of a `Feature` that requires that description. If a predefined feature is instantiated the presents of a `LineDescGroup` will override the previously defined `LineDesc`.	0-n

8.2.4 DfxMeasurementList

Many design and manufacturing tools have the ability to analyze the details of a data file and make a determination as to whether all the design rules have been met or if the parts are manufacturable within the capability of the board fabricator or assembler. The results of these analyses need to be retained so that future users of the data contained in the IPC-2581 file are aware of the improvements or risks which are apparent within the manufacturing domain.

The `DfxMeasurementList` element consists of a variety of measurements identified as `DfxMeasurement`. Each of these lists is identified separately so that the design for manufacturing analysis can be grouped according to their particular characteristic. The granularity of this grouping is dependent on the desire of the designer, fabricator, or assembler to capture the details of the Dfx analysis.

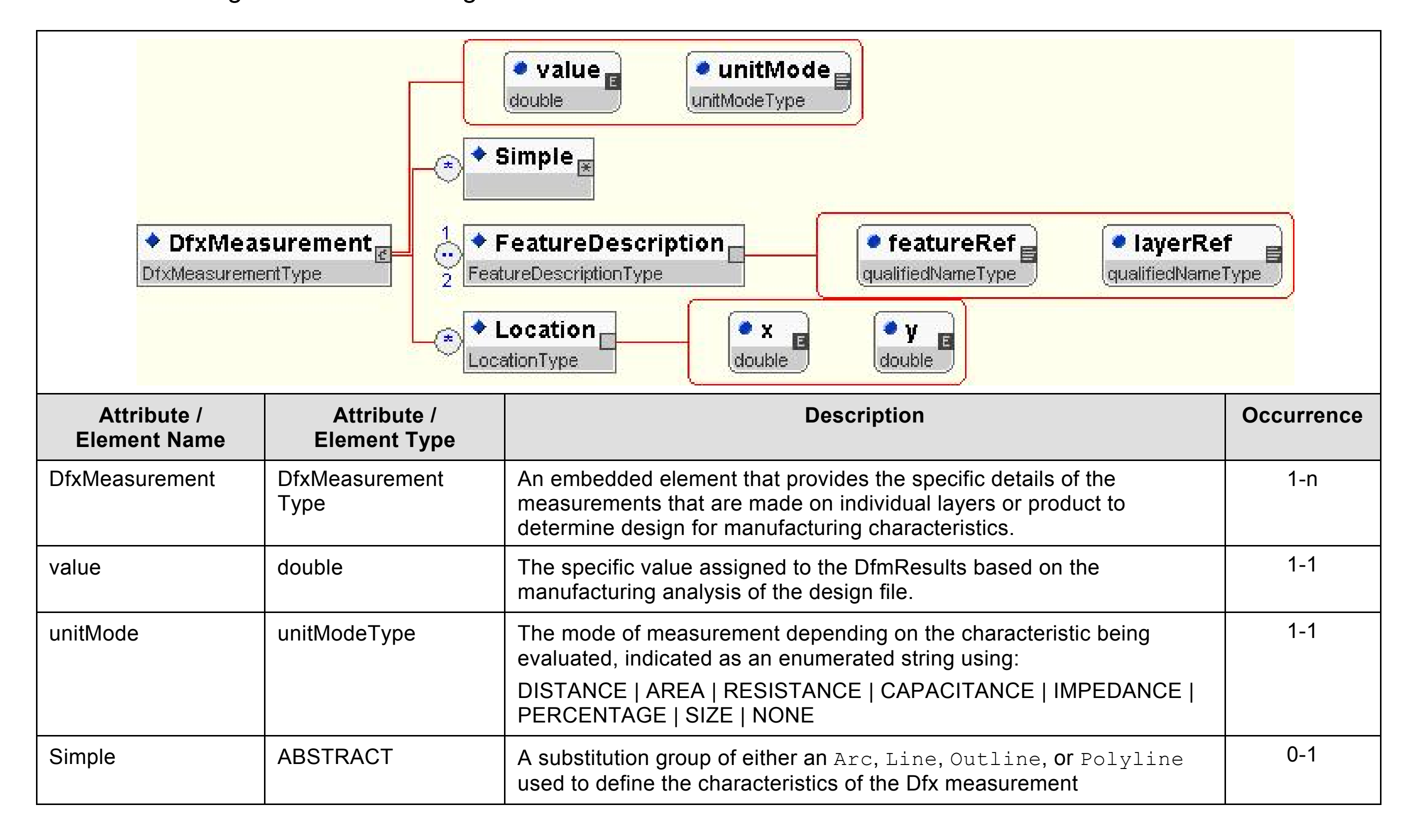
Just as there may be several `DfxMeasurementList` elements each list may contain many measurements (`DfxMeasurement`) that are described in order to indicate where the conditions afford a risk or need improvement.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DfxMeasurementList	DfxMeasurementList Type	An element consisting of a list of all the measurements made in the design for manufacturing analysis grouped in a specific category or criteria description.	1-n
name	qualifiedNameType	A unique name assigned to the `DfmMeasurementList`.	1-1
category	dfxCategoryType	A unique description defined by the user which relates to the products contained in the particular IPC-2581 file intended to provide identification for the group of the `DfxMeasurement` characteristics. The category type is an enumerated string that may be any of the following groupings COMPONENT | BOARDFAB | ASSEMBLY | TESTING | DATAQUALITY	1-1
criteria	double	The design criteria used in evaluating the measurement characteristics in order to determine whether the design as supplied by the user meets the manufacturing criteria.	1-1
DfxMeasurement	DfxMeasurementType	An embedded element that provides the specific details of the measurements that are made on individual layers or product to determine design for manufacturing characteristics.	1-n

8.2.4.1 DfxMeasurement

The `DfxMeasurement` element consists of various measurements that are related to a particular characteristic of the product. The DfxMeasurement's are made on individual layers or product to determine design for manufacturing characteristics.

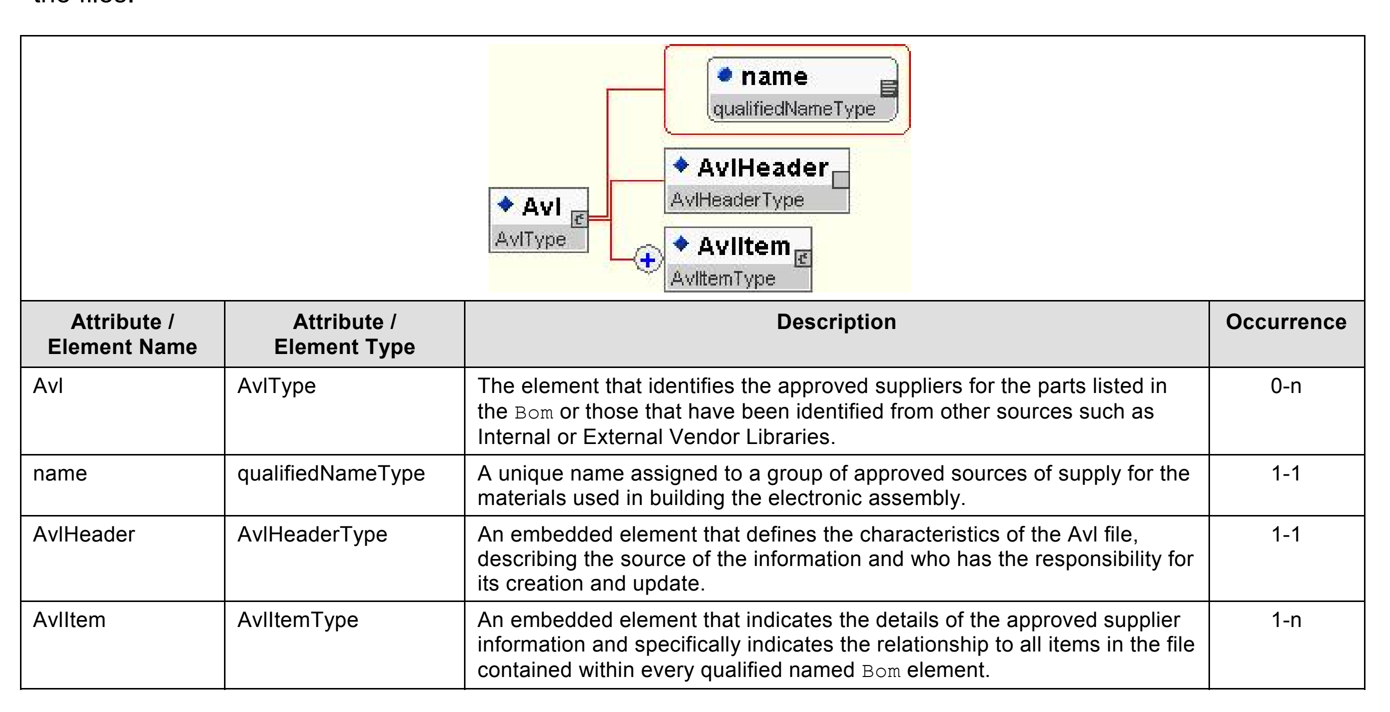


Attribute / Element Name	Attribute / Element Type	Description	Occurrence
DfxMeasurement	DfxMeasurement Type	An embedded element that provides the specific details of the measurements that are made on individual layers or product to determine design for manufacturing characteristics.	1-n
value	double	The specific value assigned to the DfmResults based on the manufacturing analysis of the design file.	1-1
unitMode	unitModeType	The mode of measurement depending on the characteristic being evaluated, indicated as an enumerated string using: DISTANCE | AREA | RESISTANCE | CAPACITANCE | IMPEDANCE | PERCENTAGE | SIZE | NONE	1-1
Simple	ABSTRACT	A substitution group of either an `Arc`, `Line`, `Outline`, or `Polyline` used to define the characteristics of the Dfx measurement	0-1

FeatureDescription	FeatureDescription Type	A nested element that can be 1 or 2 feature descriptions related to the definitions used in the Simple graphic descriptions. The second `FeatureDescription` may be either a solution or a second feature that is in conflict with the first feature.	1-2
featureRef	qualifiedNameType	A reference to the feature description in the `Set` descriptions of the `Step LayerFeature`	1-1
layerRef	qualifiedNameType	A reference to the specific layer in the `Ecad` layer section that pertains to the specifics of the `DfxMeasurement`.	1-1
Location	LocationType	The location of the image defined by the standard feature, user feature or simple graphic where the DFX measurement is applicable	0-n
x	double	The x coordinate where the `DfxMeasurement` is made relative to the point of origin of the product. The `CadHeader` defines the units of measure.	1-1
y	double	The y coordinate where the `DfxMeasurement` is made relative to the point of origin of the product. The `CadHeader` defines the units of measure.	1-1

9 APPROVED VENDOR LIST (AVL)

The `Avl` element contains the list of matching manufacturer's part numbers (MPNs) and vendor information of certain component part number's (CPN). Although there are several Bill of Materials (Bom's) there is only one approved vendor list except that the information is segmented by names of the files.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
Avl	AvlType	The element that identifies the approved suppliers for the parts listed in the `Bom` or those that have been identified from other sources such as Internal or External Vendor Libraries.	0-n
name	qualifiedNameType	A unique name assigned to a group of approved sources of supply for the materials used in building the electronic assembly.	1-1
AvlHeader	AvlHeaderType	An embedded element that defines the characteristics of the Avl file, describing the source of the information and who has the responsibility for its creation and update.	1-1
AvlItem	AvlItemType	An embedded element that indicates the details of the approved supplier information and specifically indicates the relationship to all items in the file contained within every qualified named `Bom` element.	1-n

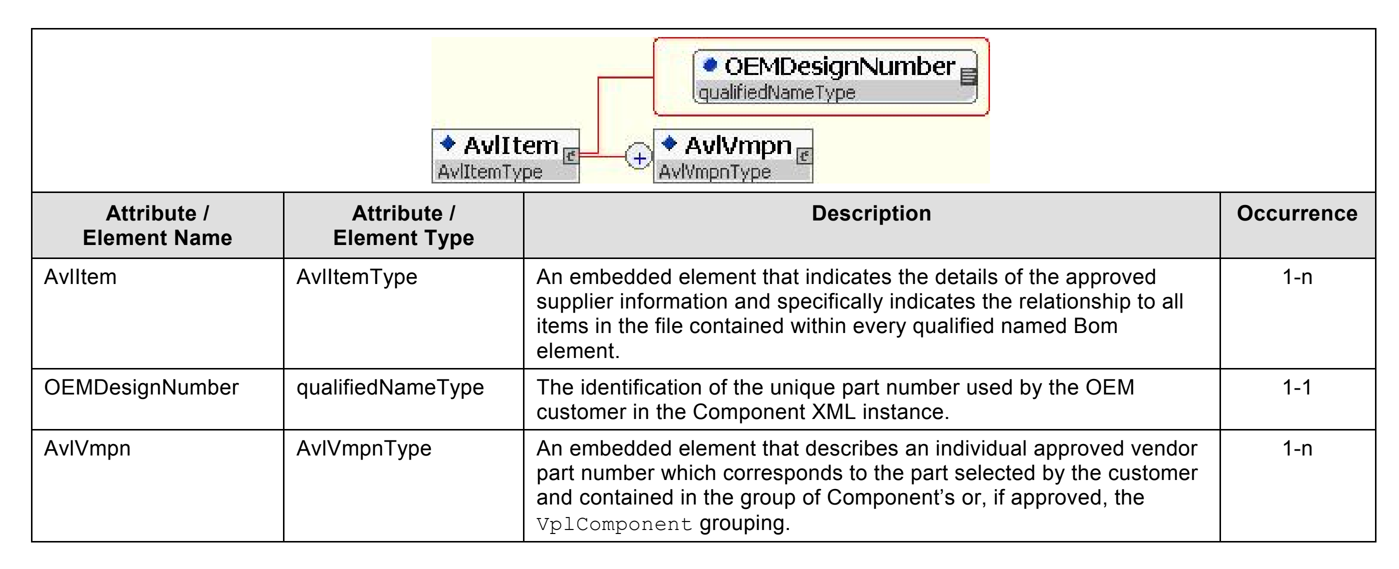
9.1 AvlHeader

The `AvlHeader` element defines the characteristics of the Avl information contained in the specific Avl file. Its occurrence is related to the name associated with the Avl file and may have different source information based on the purpose of the specific Avl. The `dateTime` attribute is used to keep account of changes that may take place in updating the information in the Avl file.

Attribute / Element Name	Attribute / Element Type	Description	Occurrence
AvlHeader	AvlHeaderType	An embedded element that defines the characteristics of the Avl file, describing the source of the information and who has the responsibility for its creation and update.	1-1
title	string	A unique title provided to the AvlHeader that distinguishes the schema instance from the `AvlDataHeader`.	1-1
source	string	The source of the information contained in the Avl file. If multiple sources exist they **shall** be so indicated with the relationship to the Avl data identified.	1-1
author	string	The individual responsible for the header creation and update. If the responsibility changes the information for this attribute must also change. It is required the person and their enterprise be contained in the `LogisticHeader` instances and the string name be identical to the id of the `Person` instance.	1-1
datetime	dateTime	The date and time that the header was created or modified.	1-1
version	positiveInteger	A positive number that defines the revision level of the AvlHeader.	1-1
comment	string	Any comment to assist in the interpretation of the Avl data.	0-1
modRef	modRefType	A reference to the mode intended for the file transfer. An emunerated string consisting of: FULL | ASSEMBLY | FABRICATION | DESIGN | TEST	0-1

9.2 AvlItem

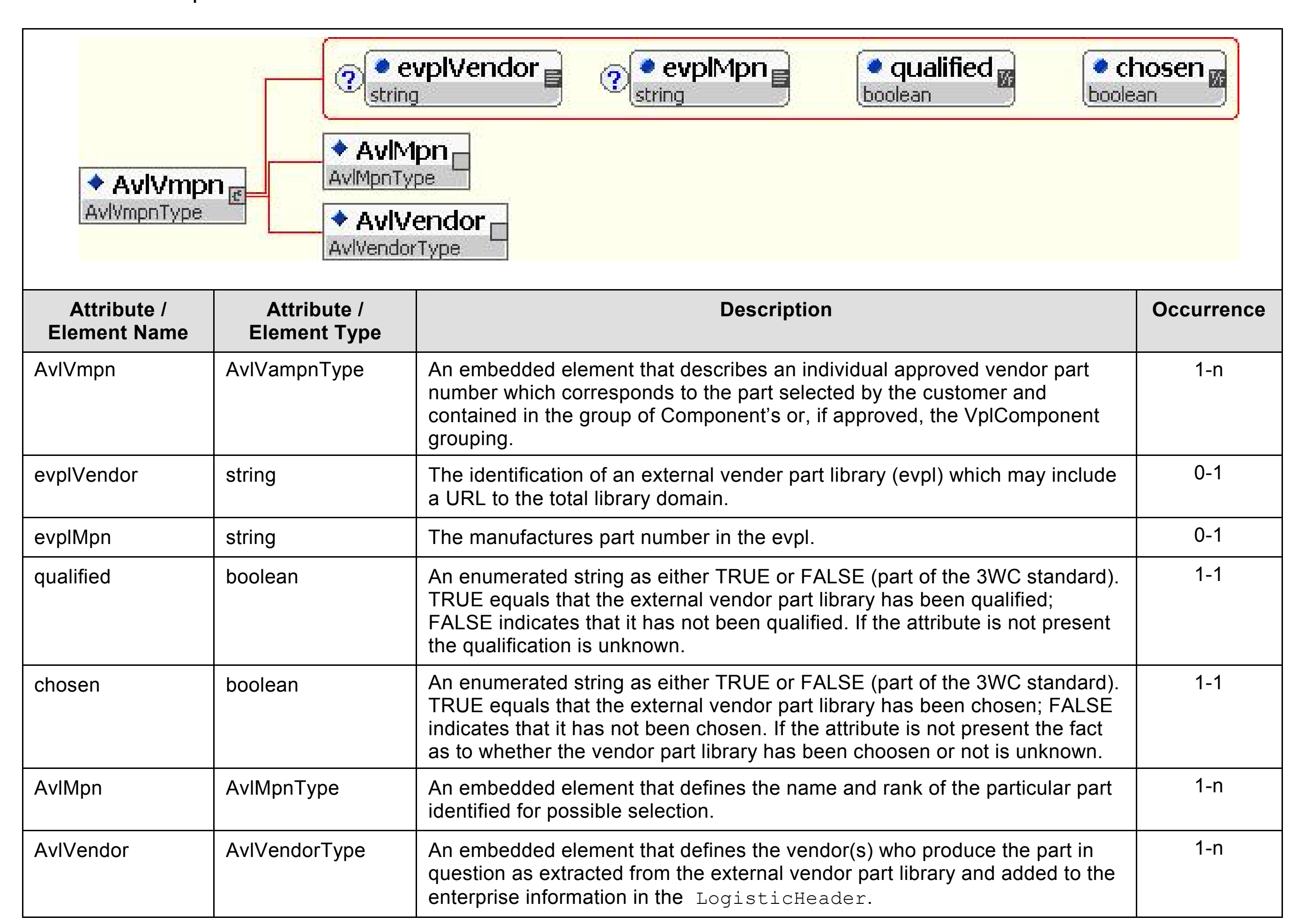
The `AvlItem` element consists of specific approved vendor information related the Bom data items and the part numbers (`OEMDesignNumber`) specified by the originator of the IPC-2581 file. Each `AvlItem` instance starts with its own `AvlDataHeader` in order to establish the relationship with the appropriate Bom. The grouping of AvlItem's provides the information on the individual relationship to vendor manufacturing part numbers (`AvlVmpnList`).



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
AvlItem	AvlItemType	An embedded element that indicates the details of the approved supplier information and specifically indicates the relationship to all items in the file contained within every qualified named Bom element.	1-n
OEMDesignNumber	qualifiedNameType	The identification of the unique part number used by the OEM customer in the Component XML instance.	1-1
AvlVmpn	AvlVmpnType	An embedded element that describes an individual approved vendor part number which corresponds to the part selected by the customer and contained in the group of Component's or, if approved, the `VplComponent` grouping.	1-n

9.2.1 AvlVmpn

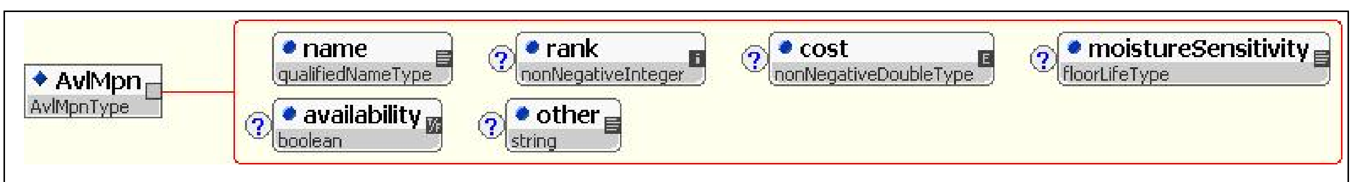
The `AvlVmpn` element represents the approved vendor part number substitution that might be implemented as an alternate to the `OEMDesignNumber` supplied by the user. The details of the information may be extracted from an external vendor part library, and if this technique is used the attributes of “qualified” and “chosen” must be included in the file.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
AvlVmpn	AvlVampnType	An embedded element that describes an individual approved vendor part number which corresponds to the part selected by the customer and contained in the group of Component’s or, if approved, the VplComponent grouping.	1-n
evplVendor	string	The identification of an external vender part library (evpl) which may include a URL to the total library domain.	0-1
evplMpn	string	The manufactures part number in the evpl.	0-1
qualified	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the external vendor part library has been qualified; FALSE indicates that it has not been qualified. If the attribute is not present the qualification is unknown.	1-1
chosen	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the external vendor part library has been chosen; FALSE indicates that it has not been chosen. If the attribute is not present the fact as to whether the vendor part library has been choosen or not is unknown.	1-1
AvlMpn	AvlMpnType	An embedded element that defines the name and rank of the particular part identified for possible selection.	1-n
AvlVendor	AvlVendorType	An embedded element that defines the vendor(s) who produce the part in question as extracted from the external vendor part library and added to the enterprise information in the `LogisticHeader`.	1-n

9.2.1.1 AvlMpn

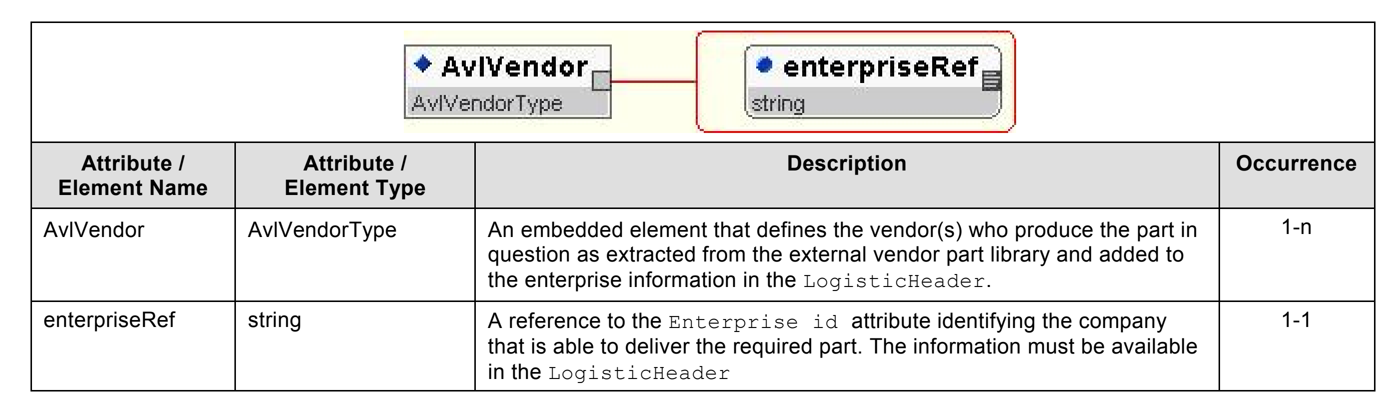
The `AvlMpn` element defines the name and ranking of the particular approved vendor part. Information is provided that identifies the characteristics of the substitution part in order to help the selection process.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
AvlMpn	AvlMpnType	An embedded element that defines the name and rank of the particular part identified for possible selection.	1-n
name	qualifiedNameType	The name of the part being suggested as an appropriate substitution	1-1
rank	nonNegativeInteger	The appropriateness of the part for its ability to serve as the same form fit and function of the original part identified as the OEMDesignNumber. The number 1 is the best ranking.	0-1
cost	nonNegativeDouble Type	The cost of the part when purchased in a reasonable quantity	0-1
moistureSensitivity	floorLifeType	An identification of the parts' ability to resist moisture penetration. It is an enumerated string that matches the requirements of J-STD-020 and is one of the following: UNLIMITED | 1_YEAR | 4_WEEKS | 168_HOURS | 72_HOURS | 48_HOURS | 24_HOURS | BAKE	0-1
availability	boolean	An enumerated string as either TRUE or FALSE (part of the 3WC standard). TRUE equals that the part is readily available; FALSE indicates that it is not. If the attribute is not present the fact as to the parts availability is unknown.	0-1
other	string	Any other information pertinent to the information about the manufacturers part number	0-1

9.2.1.2 AvlVendor

The AvlVendor element is the linkage back to the Enterprise information defining the location of the part manufacturer, distributor or other source.



Attribute / Element Name	Attribute / Element Type	Description	Occurrence
AvlVendor	AvlVendorType	An embedded element that defines the vendor(s) who produce the part in question as extracted from the external vendor part library and added to the enterprise information in the `LogisticHeader`.	1-n
enterpriseRef	string	A reference to the `Enterprise id` attribute identifying the company that is able to deliver the required part. The information must be available in the `LogisticHeader`	1-1

10 GLOSSARY

Name or Acronym	Description	Reference Name
IPC2581	Top level data structure	ODB++(X) / IPC-2511B
Avl	Approved Vendor List	ODX_AVL
Bom	Bill of Material	ODX_BOM
Ecad	Computer-Aided design information	ODX_CAD
Contents	Information about contents of the file	ODX_CONTENTS
HistoryRef	Information about order and supply data	ODX_HISTORY_REC
LogisticHeader	File change information	ODX_LOGISTICS_HEADER
VpLComponent	CAD parts library	CAD_VPL_COMPONENTS
VplComponentList	EDA Component after assembly merge	CAD_VPL_COMPONENTS LIST
CadVmpnList	CAD manufacturer part number list	CAD_VMPN_LIST
CadVmpn	CAD manufacturer part number list	CAD_VMPN
CadVplVendor	CAD component vendor	CAD VPL VENDOR
Header	Header	ODX_HEADER
AblVmpnList	Manufacturer part number list	AVL_VMPN_LIST
AvlVmpn	Manufacturer Part Number	AVL_VMPN
AvlVendor	Vendor	AVL_VENDOR

10.1 Process flow Descriptions

The detail shown in Figure 10-1 indicates the flow of data between design and manufacturing. Terminology may change as each domain performs their particular function, so the flow highlights the naming convention as the physical item moves through various steps in the process.

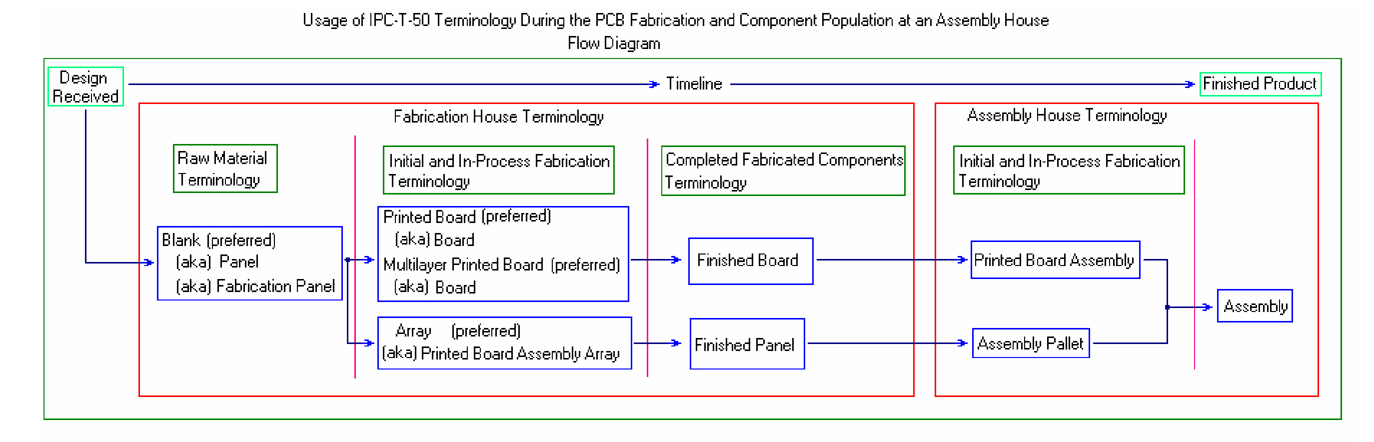


Figure 10-1 Electronic printed board design, through fabrication, assembly and test process data flow

10.2 Terms and Definitions

The definition of all terms **shall** be in accordance with IPC-T-50 and the following. An asterisk (*) by the term indicates that it is a reproduction from IPC-T-50 and is provided to assist the reader in interpretation of this standard. The order of the terms is related to the 2581 process flow shown in 10.1

Blank * 41.1339
An unprocessed or partially processed piece of base material or metal- clad base material, that has been cut from a sheet or panel, that has the rough dimensions of a printed board. (See also ''Panel.'')

Panel 41.1463
A rectangular sheet of base material or metal-clad material of predetermined size that is used for the processing of one or more printed boards and, when required, one or more test coupons. (See also ''Blank.'')

Fabrication Panel
A rectangular sheet of base material or metal-clad material of predetermined size that is used by a printed board manufacturer for the processing of one or more printed boards and, when required, one or more test coupons. (See also ''Blank.'')

Board * 60.0118
see ''Printed Board,'' and ''Multilayer Printed Board.''

Printed Board (PB) * 60.1485
The general term for completely processed printed circuit and printed wiring configurations. (This includes single-sided, double-sided and multilayer boards with rigid, flexible, and rigid-flex base materials.)

Multilayer Printed Board * 60.1227
The general term for a printed board that consist of rigid or flexible insulation materials and three or more alternate printed wiring and/or printed circuit layers that have been bonded together and electrically interconnected.

Finished Board
see "Printed Board"

Finished Panel
A rectangular sheet of base material or metal-clad material of predetermined size that is used for the processing of one or more printed board designs and, when required, one or more test coupons which is extracted from the fabrication panel to deliver to the customer or to the next level of fabrication. (see Assembly Pallet)

Assembly* 80.1327
A number of parts, subassemblies or combinations thereof joined together. (Note: This term can be used in conjunction with other terms listed herein, e.g., ''Printed Board Assembly'')

Printed Board Assembly* 80.0911
The generic term for an assembly that uses a printed board for component mounting and interconnecting purposes.

Array* 22.0049
A group of elements or circuits arranged in rows and columns on a base material.

Printed Board Assembly Array
A group of assemblies, all of the same design, arranged in rows and columns on a panel.

Assembly Pallet
The generic term for the assembly that uses a finished panel, as delivered from the board fabricator, of the same or different designs, for element and circuit component mounting and attachment to the board interconnections layers. The board arrangement on the pallet may be random or in the form of an array; the pallet may also include coupons for testing.

10.3 Enumerated strings of 2581

The following enumerations exists for 2581 data restrictions. The terms used in the started are intended to relate to the definitions shown in 10.2.

BOARD | BOARDPANEL | ASSEMBLY | ASSEMBLYPALLET | COUPON

11 REFERENCE INFORMATION

The following sections define reference documents that are useful in clarifying the products or process of the industry or provide additional insight into the subject of data modeling or released information models.

11.1 IPC (1)

IPC-1050 *Terms and Definitions*

IPC-D-310 *Guidelines for Artwork Generation and Measurement Techniques for Printed Circuits*

IPC-D-325 *Documentation Requirements for Printed Boards, Assemblies and Support Drawings*

IPC-2220 series *Design Standard for Printed Boards and Printed Board Assemblies*

IPC-2501 *Definition for Web-Based Exchange of XML Data*

IPC-2510 *Implementation of Product Manufacturing Description Data and Transfer Methodology*

IPC-2571 *Generic Requirements for Electronics Manufacturing Supply Chain Communication – Product Data eXchange (PDX)*

IPC-2576 *Sectional Requirements for Electronics Manufacturing Supply Chain Communication of As-Built Product Data – Product Data eXchange (PDX)*

IPC-2577 *Sectional Requirements for the Supply Chain (B2B) Communication of Quality Product Data*

IPC-2578 *Sectional Requirements for Supply Chain Communication of Bill of Material and Product Design Configuration Data - Product Data eXchange (PDX)?*

IPC-2615 *Printed Board Dimensions and Tolerances*

IPC-4101 *Specification for Base Materials for Rigid Board and Multilayer Printed Boards*

IPC-4103 *Specification for Base Materials for High Speed/ High Frequency Applications*

IPC-4104 *Specification for High Density Interconnect (HDI) and Microvia Materials*

IPC-7351 *Requirements for Design of Land Patterns*

11.2 American National Standards Institute (2)

ANSI X3/TR-1-77 *American National Dictionary for Information Processing*

ANSI X3.12 *Subroutine Record Format Standardization*

ANSI Y14.5 *Dimensioning and Tolerancing for Engineering Drawing*

ANSI Y32.1 *Logic Diagram Standards*

ANSI Y32.16 *Electrical and Electrical Reference Designators*

ANSI Z210.1 *Metric Practice Guide (ASTM 380-72)*

11.3 Department of Defense (3)

DoD-STD-100 *Engineering Drawings*

11.4 Electronic Industries Association (4)

EDIF 4 0 0 *Electronic Data Interchange Format*

11.5 International Organization for Standards (ISO)

ISO STEP Documentation:

ISO 10303-AP210 *Electronic Assembly, Interconnect, and Packaging Design*

ISO 10303-AP212 *Electrotechnical Design & Installation*

AP220 *Process Planning, Manufacturing, and Assembly of Layered Electronic Products*

AP221 *Process Plant Functional Data & Schematic Representation*

Appendix A
IPC-7351 Naming Convention for Land Patterns

Surface Mount Land Patterns

Component, Category	Land Pattern Name
Amplifiers	**AMP_** Mfr.'s Part Number
Ball Grid Array's, Inch Based (1.27mm / 0.05" Pitch)	**BGA127P** + Number of Pin Columns **X** Number of Pin Rows **-** Pin Qty
Ball Grid Array's, Metric Based (1.50mm Pitch)	**BGA150P** + Number of Pin Columns **X** Number of Pin Rows **-** Pin Qty
Ball Grid Array's, Metric Based (1.00mm Pitch)	**BGA100P** + Number of Pin Columns **X** Number of Pin Rows **-** Pin Qty
Ball Grid Array's, Metric Based (0.80mm Pitch)	**BGA80P** + Number of Pin Columns **X** Number of Pin Rows **-** Pin Qty
Ball Grid Array's, Metric Based (0.75mm Pitch)	**BGA75P** + Number of Pin Columns **X** Number of Pin Rows **-** Pin Qty
Ball Grid Array's, Metric Based (0.65mm Pitch)	**BGA65P** + Number of Pin Columns **X** Number of Pin Rows **-** Pin Qty
Ball Grid Array's, Metric Based (0.50mm Pitch)	**BGA50P** + Number of Pin Columns **X** Number of Pin Rows **-** Pin Qty
Ball Grid Array's w/Staggered Pins (1.27mm Pitch)	**SBGA127P** + Number of Pin Columns **X** Number of Pin Rows **-** Pin Qty
Batteries	**BAT_** Mfr.'s Part Number
Capacitors, Chip	**CAPC** + Body Size in Metric
Capacitors, Tantalum	**CAPT** + Body Size in Metric
Capacitors, Aluminum Electrolytic	**CAPAE** + Diameter + **W** Height + **H**
Capacitors, Variable	**CAPV_** Mfr.'s Part Number
Capacitor Network, Chip	**CAPN_** Mfr.'s Part Number
Capacitors, Miscellaneous	**CAP_** Mfr.'s Part Number
Ceramic Flat Packages	**CFP127P** + Lead Span Nominal **-** Pin Qty
Column Grid Array's	**CGA** + Number of Pin Columns **X** Number of Pin Rows **-** Pin Qty
Crystals	**XTAL_** Mfr.'s Part Number
Diodes, Molded	**DIOSMA, B & C**
Diodes, MELF	**DIOMELF** + Body Size in Metric
Diodes, Miscellaneous	**DIO_** Mfr.'s Part Number
Diodes, Bridge Rectifiers	**DIOB_** Mfr.'s Part Number
Ferrite Beads	**FB_** Mfr.'s Part Number
Fiducials	**FID** + Pad Size X Soldermask Size in Metric
Filters	**FIL_** Mfr.'s Part Number
Fuses	**FUSE_** Mfr.'s Part Number
Fuse, Resettable	**FUSER_** Mfr.'s Part Number
Inductors, Chip	**INDC** + Body Size in Metric
Inductors, Molded	**INDM** + Body Size in Metric
Inductors, Precision Wire Wound	**INDP** + Body Size in Metric
Inductors, Miscellaneous	**IND_** Mfr.'s Part Number
Inductor Networks, Chip	**INDN_** Mfr.'s Part Number
Keypad	**KEYPAD_** Mfr.'s Part Number
LEDS	**LED_** Mfr.'s Part Number
LEDS, Chip	**LED** + Body Size in Metric
Liquid Crystal Display	**LCD_** Mfr.'s Part Number
Microphones	**MIC_** Mfr.'s Part Number
Opto Isolators	**OPTO_** Mfr.'s Part Number
Oscillators	**OSC_** Mfr.'s Part Number
Plastic Leaded Chip Carriers Square	**PLCC-** Pin Qty
Plastic Leaded Chip Carriers Rectangular	**PLCCR-** Pin Qty
Plastic Leaded Chip Carrier Sockets Square	**PLCCS-** Pin Qty
Plastic Leaded Chip Carrier Sockets Rectangular	**PLCCRS-** Pin Qty
Plastic Quad Flat Packages, 0.635mm Pitch, Pin 1 Side	**PQFPS-** Pin Qty
Plastic Quad Flat Packages, 0.635mm Pitch, Pin 1 Center	**PQFPC-** Pin Qty
Bumper Quad Flat Packages, 0.635mm Pitch, Pin 1 Side	**BQFPS-** Pin Qty
Bumper Quad Flat Packages, 0.635mm Pitch, Pin 1 Center	**BQFPC-** Pin Qty
Quad Flat Packages, 1.00mm Pitch	**QFP100P** + Lead Span L1 **X** Lead Span L2 Nominal **-** Pin Qty
Quad Flat Packages, 0.80mm Pitch	**QFP80P** + Lead Span L1 **X** Lead Span L2 Nominal **-** Pin Qty
Quad Flat Packages, 0.65mm Pitch	**QFP65P** + Lead Span L1 **X** Lead Span L2 Nominal **-** Pin Qty
Shrink Quad Flat Packages, 0.50mm Pitch	**SQFP50P** + Lead Span L1 **X** Lead Span L2 Nominal **-** Pin Qty
Shrink Quad Flat Packages, 0.40mm Pitch	**SQFP40P** + Lead Span L1 **X** Lead Span L2 Nominal **-** Pin Qty
Shrink Quad Flat Packages, 0.30mm Pitch	**SQFP30P** + Lead Span L1 **X** Lead Span L2 Nominal **-** Pin Qty
Thin Quad Flat Packages, 0.80mm Pitch, Height ≤ 1.60mm	**TQFP80P** + Lead Span L1 **X** Lead Span L2 Nominal **-** Pin Qty
Thin Quad Flat Packages, 0.65mm Pitch, Height ≤ 1.60mm	**TQFP65P** + Lead Span L1 **X** Lead Span L2 Nominal **-** Pin Qty
Thin Quad Flat Packages, 0.50mm Pitch, Height ≤ 1.60mm	**TSQFP50P** + Lead Span L1 **X** Lead Span L2 Nominal **-** Pin Qty
Thin Quad Flat Packages, 0.40mm Pitch, Height ≤ 1.60mm	**TSQFP40P** + Lead Span L1 **X** Lead Span L2 Nominal **-** Pin Qty
Thin Quad Flat Packages, 0.30mm Pitch, Height ≤ 1.60mm	**TSQFP30P** + Lead Span L1 **X** Lead Span L2 Nominal **-** Pin Qty
Ceramic Quad Flat Packages, 1.27mm Pitch	**CQFP127P** + Lead Span Nominal **-** Pin Qty
Ceramic Quad Flat Packages, 0.80mm Pitch	**CQFP80P** + Lead Span Nominal **-** Pin Qty
Ceramic Quad Flat Packages, 0.635mm Pitch	**CQFP635P** + Lead Span Nominal **-** Pin Qty

Surface Mount Land Patterns (continued)

Component, Category	Land Pattern Name
Quad Flat No Lead Packages 0.80mm Pitch	**QFN80P -** Body Width **X** Body Length in Metric **-** Pin Qty
Quad Flat No Lead Packages 0.65mm Pitch	**QFN65P -** Body Width **X** Body Length in Metric **-** Pin Qty
Quad Flat No Lead Packages 0.50mm Pitch	**QFN50P -** Body Width **X** Body Length in Metric **-** Pin Qty
Quad Flat No Lead Packages 0.40mm Pitch	**QFN40P -** Body Width **X** Body Length in Metric **-** Pin Qty
Quad Leadless Ceramic Chip Carriers	**LCC-** Pin Qty
Relays	**RELAY_**Mfr.'s Part Number
Resistors, Chip	**RESC** + Body Size in Metric
Resistors, Molded	**RESM** + Body Size in Metric
Resistor, MELF	**RESMELF** + Body Size in Metric
Resistor Networks, Chip	**RESN_**Mfr.'s Part Number
Small Outline IC, J-Leaded 300, 350, 400, 450 mil Body Width (Pitch 1.27mm)	**SOJ** + Body Width in mils **-** Pin Qty
Small Outline Integrated Circuit, 1.27mm Pitch (Standard 50 mil Pitch SOIC's)	**SOIC127P** + Lead Span Nominal **-** Pin Qty
Small Outline Packages, 1.27mm Pitch (Non-Standard 50 mil Pitch SOIC's)	**SOP127P** + Lead Span Nominal **-** Pin Qty
Small Outline Packages, 1.00mm Pitch	**SOP100P** + Lead Span Nominal **-** Pin Qty
Small Outline Packages, 0.80mm Pitch	**SOP80P** + Lead Span Nominal **-** Pin Qty
Small Outline Packages, 0.65mm Pitch	**SOP65P** + Lead Span Nominal **-** Pin Qty
Small Outline Packages, 0.635mm Pitch	**SOP635P** + Lead Span Nominal **-** Pin Qty
Shrink Small Outline Packages, 0.50mm Pitch	**SSOP50P** + Lead Span Nominal **-** Pin Qty
Shrink Small Outline Packages, 0.40mm Pitch	**SSOP40P** + Lead Span Nominal **-** Pin Qty
Shrink Small Outline Packages, 0.30mm Pitch	**SSOP30P** + Lead Span Nominal **-** Pin Qty
Thin Small Outline Packages, Height is ≤ 1.60mm, 1.27mm Pitch	**TSOP127P** + Lead Span Nominal **-** Pin Qty
Thin Small Outline Packages, Height is ≤ 1.60mm, 1.00mm Pitch	**TSOP100P** + Lead Span Nominal **-** Pin Qty
Thin Small Outline Packages, Height is ≤ 1.60mm, 0.80mm Pitch	**TSOP80P** + Lead Span Nominal **-** Pin Qty
Thin Small Outline Packages, Height is ≤ 1.60mm, 0.65mm Pitch	**TSOP65P** + Lead Span Nominal **-** Pin Qty
Thin Shrink Small Outline Packages, Height is ≤ 1.60mm, 0.55mm Pitch	**TSSOP55P** + Lead Span Nominal **-** Pin Qty
Thin Shrink Small Outline Packages, Height is ≤ 1.60mm, 0.50mm Pitch	**TSSOP50P** + Lead Span Nominal **-** Pin Qty
Thin Shrink Small Outline Packages, Height is ≤ 1.60mm, 0.40mm Pitch	**TSSOP40P** + Lead Span Nominal **-** Pin Qty
Thin Shrink Small Outline Packages, Thin (Height is ≤ 1.60mm) 0.30mm Pitch	**TSSOP30P** + Lead Span Nominal **-** Pin Qty
SOD123	**DIOSOD123**
SOT23 Three Pin Package	**SOT23-3**
SOT23 Five Pin Package	**SOT23-5**
SOT23 Six Pin Package	**SOT23-6**
SOT23 Eight Pin Package	**SOT23-8**
SOT89	**SOT89**
SOT143	**SOT143**
SOT143 Reverse	**SOT143R**
SOT223 Four Total Pins (Includes GND Tab)	**SOT223-4**
SOT223 Five Total Pins (Includes GND Tab)	**SOT223-5**
SOT223 Six Total Pins (Includes GND Tab)	**SOT223-6**
SOT323	**SOT323**
SOT353	**SOT353**
SOT363	**SOT363**
SOT404	**SOT404**
Speakers	**SPKR_**Mfr's Part Number
Switches	**SW_**Mfr.'s Part Number
Test Points, Round	**TP** + Pad Size in Metric (1 place left of decimal and 2 places right of decimal, Example **TP100** = 1.00mm)
Test Points, Square	**TPS** + Pad Size in Metric (1 place left of decimal and 2 places right of decimal)
Test Points, Rectangle	**TP** + Pad Length **X** Pad Width in Metric (1 place left of decimal and 2 places right of decimal)
Thermistors	**THERM_**Mfr.'s Part Number
TO236	**TO236**
T0252	**TO252**
TO263 (Includes GND Tab)	**TO263-** Pin Qty
Transducers (IRDA's)	**XDCR_**Mfr.'s Part Number
Transient Voltage Suppressors	**TVS** + Body Size in Metric
Transient Voltage Suppressors, Polarized	**TVSP** + Body Size in Metric
Transistor Outlines, Custom	**TRANS_**Mfr.'s Part Number
Transformers	**XFMR_**Mfr.'s Part Number
Trimmers & Potentiometers	**TRIM_**Mfr.'s Part Number
Tuners	**TUNER_**Mfr.'s Part Number
Varistors	**VAR_**Mfr.'s Part Number
Voltage Controlled Oscillators	**VCO_**Mfr.'s Part Number
Voltage Regulators, Custom	**VREG_**Mfr.'s Part Number

Through Hole Land Patterns

Component, Category	Land Pattern Name
Amplifiers	**AMP_**Mfr.'s Part Number
Batteries	**BAT_**Mfr.'s Part Number
Bridge Rectifiers	**DIOB_**Mfr.'s Part Number
Capacitors, Non Polarized Axial	**CAPA** + Pin Spacing **-** Body Length **X** Body Diameter in Metric
Capacitors, Non Polarized Radial, Round	**CAPR** + Pin Spacing **-** Body Diameter **X** Component Height in Metric
Capacitors, Non Polarized Radial, Oval	**CAPR** + Pin Spacing **-** Body Width **X** Body Length **X** Component Height in Metric
Capacitors, Polarized Axial	**CAPPA** + Pin Spacing **-** Body Length **X** Body Diameter in Metric
Capacitor, Polarized Radial	**CAPPR** + Pin Spacing **-** Body Diameter **X** Component Height in Metric
Converters	**CONV_**Mfr.'s Part Number
Crystals	**XTAL_**Mfr.'s Part Number
Diodes, JEDEC Standard	**DO-** JEDEC Part Number
Diodes, Miscellaneous	**DIO_**Mfr.'s Part Number
Dual-In-Line Packages	**DIP** + Pin Qty + Pin Span in MILS
Dual-In-Line Sockets	**DIPS** + Pin Qty + Pin Span in MILS
Ferrite Beads	**FB_**Mfr.'s Part Number
Filters	**FIL_**Mfr's Part Number
Fuses	**FUSE_**Mfr.'s Part Number
Fuses, Resettable	**FUSER_**Mfr.'s Part Number
Headers, .100" Pin Centers	**HDR** + Number of Rows **X** Number of pins per Row
Heat Sinks	**HSINK_**Mfr.'s Part Number
Inductors	**IND_**Mfr.'s Part Number
Jumpers, Wire	**JUMP** + Distance between Pads in Metric
LED's	**LED_**Mfr.'s Part Number
Liquid Crystal Display	**LCD_**Mfr.'s Part Number
Microphones	**MIC_**Mfr.'s Part Number
Mounting Holes Nonplated	**MTG** + Hole Size in Metric
Mounting Holes Plated	**MTG** + Hole Size_Pad Size in Metric
Mounting Holes Plated with 8 Vias	**MTG** + Hole Size_Pad Size in Metric - **VIA**
MOV	**MOV_**Mfr.'s Part Number
Opto Isolators	**OPTO_**Mfr.'s Part Number
Oscillators	**OSC_**Mfr.'s Part Number
PAD	**PAD** + Pad Size **X** Hole Size in Metric + **H**
Photo Detectors	**PHODET_**Mfr.'s Part Number
Pin Grid Array's	**PGA** + Number of Pin Rows **X** Number of Pin Columns **-** Pin Qty
Regulators	**REG_**Mfr.'s Part Number
Relays	**RELAY_**Mfr.'s Part Number
Resistors, Axial Leads	**RES** + Pad Spacing **-** Body Length **X** Body Diameter in Metric
Resistor Networks	**SIP** + Pin Qty
Shield, off the shelf	**SHIELD_**Mfr.'s Part Number
Shield, Custom	**SHIELD** + Body Length **X** Body Width in Metric
Speakers	**SPKR_**Mfr's Part Number
Stiffners	**STIF_**Mfr's Part Number
Switches	**SW_**Mfr.'s Part Number
Test Points, Round	**TP** + Pad Size **X** Hole Size in Metric + **H**
Test Points, Square	**TPS** + Pad Size **X** Hole Size in Metric + **H**
Test Points, Top Pad & Bottom Pad are Different Size	**TP** + Top Pad **X** Bottom Pad **X** Hole Size in Metric + **H**
Thermistors	**THERM_**Mfr.'s Part Number
Transducers (IRDA's)	**XDCR_**Mfr.'s Part Number
Transient Voltage Suppressors	**TVS** + Mfr.'s Part Number
Transient Voltage Suppressors, Polarized	**TVSP** + Mfr.'s Part Number
Transistor Outlines, Standard	**TO-** JEDEC Number
Transistor Outlines, Custom	**TRANS_**Mfr.'s Part Number
Transformers	**XFMR_**Mfr.'s Part Number
Trimmers & Potentiometers	**TRIM_**Mfr.'s Part Number
Tuners	**TUNER_**Mfr.'s Part Number
Varistors	**VAR_**Mfr.'s Part Number
Voltage Controlled Oscillator	**VCO_**Mfr.'s Part Number
Voltage Regulators	**TO-** JEDEC Number

Connector Land Patterns

Library Name	Land Pattern Name
AMP™	Series Number – Pin Qty
BERG™	Part Number
CUI-STACK	Part Number
HIROSE™	Part Number
JST™	Part Number
KYCON™	Part Number
MOLEX™	Series Number – Pin Qty
SAMTEC™	Part Number
SWITCHCRAFT™	Part Number
CONNECTORS (Miscellaneous Connector Libraries)	
3M™	3M_Part Number
AMPHENOL™	AMPHENOL_Part Number
AVX™	AVX_Part Number
ITT CANNON™	ITT_Part Number
JWT™	JWT_Part Number
PHOENIX™	PHOENIX_Part Number
SIEMENS™	SIEMENS_Part Number
SPEEDTECH™	SPEEDTECH_Part Number
STEWART™	STEWART_Part Number
YAMAICHI™	YAMAICHI_Part Number

SYNTAX EXPLANATIONS:

The **+** (plus sign) stands for "in addition to" (no space between the prefix and the body size)
The **_** (under score) is the separator between the Prefix and the Mfr Part Number.
The **-** (dash) is used to separate the pin qty.
The **X** (capital letter X) is used instead of the word "by" to separate two numbers such as height **X** width like "Quad Packages".
Connector Series Number:

In these libraries such as AMP & MOLEX the "Series Number" is used and the pin qty. Molex Example: **90663-60**
The other connector libraries will just contain the manufacturer's part number. We did a study and could not find any overlapping manufacture part numbers for 20 different connector manufacturers, so it's safe to use it.

SUFFIXES For Every Common SMT Land Pattern to Describe Environment Use (This is the last character in every name)
Note: This excludes the BGA and QFN families as they only come in Nominal Environment Condition.

- **M**.....................Most Material Condition (Level A)
- **N** ....Nominal Material Condition (Level B)
- **L**......................Least Material Condition (Level C)

SUFFIXES for Alternate Components that do not follow the JEDEC, EIA or IEC Standard

- **A** ....Alternate Component (used primarily for SOP & QFP when Component Tolerance or Height is different)
- **B** ....Second Alternate Component

SUFFIXES for JEDEC and EIA Standard parts that have several alternate packages

- **AA, AB, AC** ....JEDEC or EIA Component Identifier (Used primarily on Chip Resistors, Inductors and Capacitors)

SUFFIXES for Through Hole Mounting Holes

VIA..................Vias (Mounting Holes with 8 vias)

Surface Mount Land Patterns

IPC-735* Component Family Breakdown:

IPC-7351 = IEC 61188-5-1, Generic requirements- Attachment (land/joint) considerations – **General Description**

IPC-7352 = IEC 61188-5-2, Sectional requirements - Attachment (land/joint) considerations – **Discrete Components**

IPC-7353 = IEC 61188-5-3, Sectional requirements - Attachment (land/joint) considerations – **Gull-wing leads, two sides (SOP)**

IPC-7354 = IEC 61188-5-4, Sectional requirements - Attachment (land/joint) considerations – **J leads, two sides (SOJ)**

IPC-7355 = IEC 61188-5-5, Sectional requirements - Attachment (land/joint) considerations – **Gull-wing leads, four sides (QFP)**

IPC-7356 = IEC 61188-5-6, Sectional requirements - Attachment (land/joint) considerations – **J leads, four sides (PLCC)**

IPC-7357 = IEC 61188-5-7, Sectional requirements - Attachment (land/joint) considerations – **Post leads, two sides (DIP)**

IPC-7358 = IEC 61188-5-8, Sectional requirements - Attachment (land/joint) considerations – **Area Array Components (BGA)**

IPC-7359 = NO IEC Document, Sectional requirements - Attachment (land/joint) considerations – **No Lead Components (LCC)**

Component Zero Rotations Pin 1 Location:

1) Chip Capacitors, Resistors and Inductors (RES, CAP and IND) – **Pin 1 (Positive Pin) on Left**
2) Molded Inductors (INDM), Resistors (RESM) and Tantalum Capacitors (CAPT) – **Pin 1 (Positive Pin) on Left**
3) Precision Wire-wound Inductors (INDP) – Pin 1 **(Positive Pin) on Left**
4) MELF Diodes – **Pin 1 (Cathode) on Left**
5) Aluminum Electrolytic Capacitors (CAPAE) – **Pin 1 (Positive) on Left**
6) SOT Devices (SOT23, SOT23-5, SOT223, SOT89, SOT143, etc.) – **Pin 1 Upper Left**
7) TO252 & TO263 (DPAK Type) Devices – **Pin 1 Upper Left**
8) Small Outline Gullwing ICs (SOIC, SOP, TSOP, SSOP, TSSOP) – **Pin 1 Upper Left**
9) Ceramic Flat Packs (CFP) – **Pin 1 Upper Left**
10) Small Outline J Lead ICs (SOJ) – **Pin 1 Upper Left**
11) Quad Flat Pack ICs (PQFP, SQFP) – **Pin 1 Upper Left**
12) Ceramic Quad Flat Packs (CQFP) – **Pin 1 Upper Left**
13) Bumper Quad Flat Pack ICs (BQFP Pin 1 Center) – **Pin 1 Top Center**
14) Plastic Leaded Chip Carriers (PLCC) – **Pin 1 Top Center**
15) Leadless Chip Carriers (LCC) – **Pin 1 Top Center**
16) Quad Flat No-Lead ICs (QFN) QFNS, QFNRV, QFNRH – **Pin 1 Upper Left**
17) Ball Grid Arrays (BGA) – **Pin A1 Upper Left**

Appendix B
Panel Instance File

The following is the XML instance file for the panel shown in the illustration below.

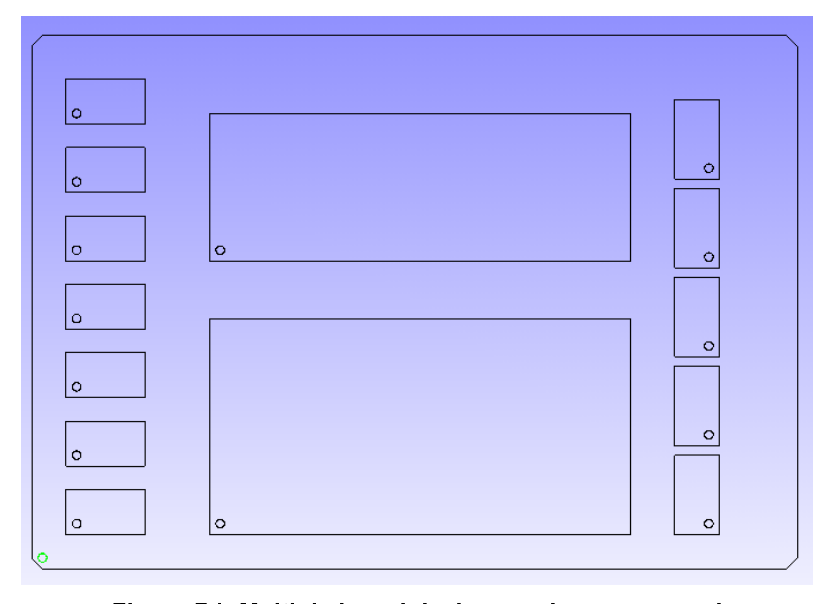


Figure B1 Multiple board designs and coupon panel

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            <Profile>
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